ENGINEERING LIBRARY

OCT 22 1947

AGRICULTURAL ENGINEERING

OCTOBER · 1947

Framing Farm Buildings — Some Engineering Considerations *R. A. Glaze*

Soil Erosion Studies—Soil Transportation by Surface Flow *W. D. Ellison*

A Study of the Withdrawal Resistance of Roofing Nails *Henry Giese*

Pressure-Membrane Apparatus — Construction and Use *L. A. Richards*

Research Procedures for Cooperative Projects with Limited Personnel *F. A. Brooks*

A.S.A.E. Fall Meeting • Chicago, Ill., December 15-17, 1947

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Nothing Else on Wheels

Can do it!

Big new sprayers of the multi-nozzle type and mighty Case "LA" tractors are bringing new speed to spraying. With a rig of this type, one man becomes a spray crew capable of covering many trees in a few hours. Such power equipment brings a much-needed answer to the problem of better insect and disease control with fewer man-hours, exemplifies the importance of ample tractor power.

Owners of rigs like this report the Case "LA" as the only wheel tractor with sufficient power to do both ends of the job — to operate the big-capacity high-pressure pump at a uniform speed and to keep the outfit moving steadily between the rows of trees. Using the "LA" eliminates need for an auxiliary engine on the pump, reduces first cost and cuts operating expenses. At the same time, power take-off drive from the tractor simplifies one-man operation.

CASE ★ ★

The Yield that Counts is Yield per Man. Present scarcity and high cost of farm labor emphasize that production per man is the dominant influence on costs of products and on earnings of farmers. Yield per acre means but little except as it affects yield per man-hour.

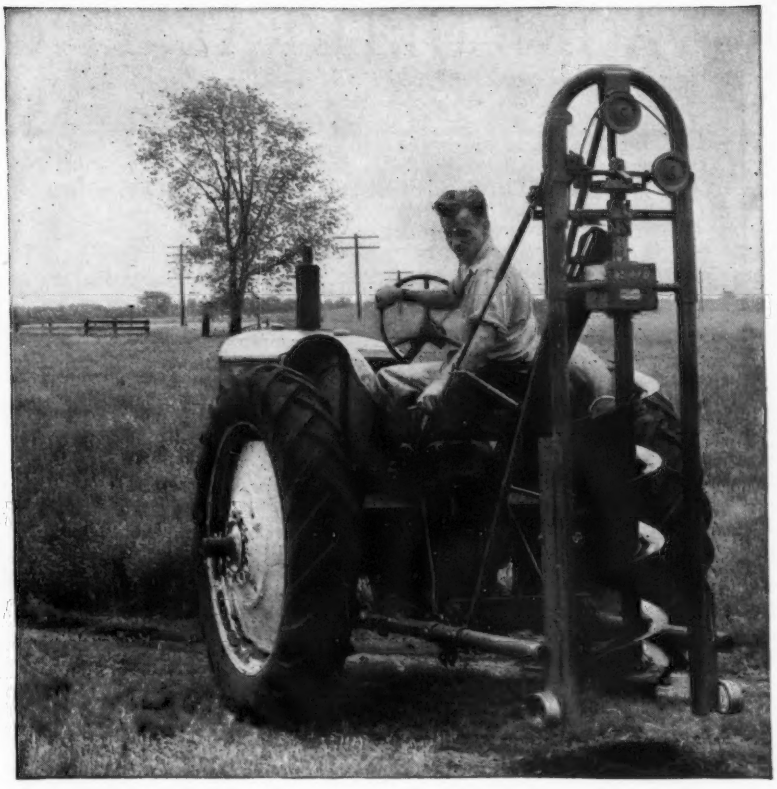
Case policy is to provide farm machines that serve three major purposes: (1) Increase acreage per man-hour; (2) improve yields per acre by more effective and more timely work; and (3) facilitate practices that sustain the permanent productivity of land. Case educational films, booklets and posters, available for your use, are designed to promote these purposes.

J. I. CASE CO., Racine, Wis.

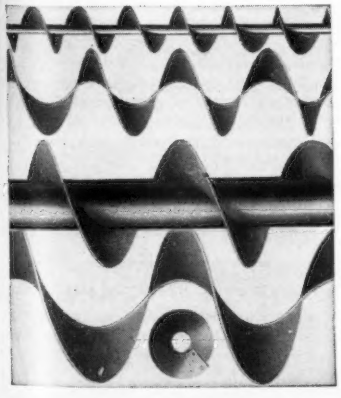
SERVING AGRICULTURE SINCE 1842

CLEAN, ROUND HOLES . . . FAST!

CONTINENTAL HOLE DIGGER USES LINK-BELT SCREW CONVEYOR



Below: Available in continuous rolled flight, or in sectional type, and in practically any gage, diameter or pitch, unmounted or welded on pipe of desired size, Link-Belt Screw Conveyor affords the designer many opportunities for utilizing this versatile type of conveyor.



As a post hole auger, Link-Belt Helicoid (screw) conveyor is a "natural." The continuous rolled flighting, welded to the steel pipe, into a unit without joints or seams removes the earth smoothly and cleanly. It is driven by the power take-off of the tractor.

This is one interesting example of the numerous and growing applications of Link-Belt screw conveyor to farm implements and machinery of many kinds.

Consult Link-Belt Company, originators of "Helicoid" continuous rolled flight conveyor, and largest producer, for information and suggestions in applying screw conveyor to your particular needs and purposes.

LINK-BELT COMPANY

Chicago 8, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities. 10.771

LINK-BELT SCREW CONVEYOR

COLLARS · COUPLINGS · HANGERS · TROUGHS · BOX ENDS · FLANGES · THRUSTS · DRIVES

AGRICULTURAL ENGINEERING

Established 1920

CONTENTS FOR OCTOBER, 1947

Vol. 28, No. 10

EDITORIAL 435

FRAMING FARM BUILDINGS 437
By R. A. Glaze

SOIL EROSION STUDIES — PART VII
SOIL TRANSPORTATION BY SURFACE FLOW 442
By W. D. Ellison and O. T. Ellison

THE WITHDRAWAL RESISTANCE OF
ROOFING NAILS 445
By Henry Giese

PRESSURE-MEMBRANE APPARATUS —
CONSTRUCTION AND USE 451
By L. A. Richards

RESEARCH PROCEDURES FOR COOPERATIVE PROJECTS
WITH LIMITED PERSONNEL 455
By F. A. Brooks

CALCULATIONS FOR LAND GRADATION 461
By Grant E. Chugg

WHY NOT BUILD DAIRY BARNS THAT THE
COWS CAN PAY FOR? 464
By B. G. Perkins

RESEARCH NOTES 466

NEWS SECTION 468

PERSONNEL SERVICE BULLETIN 476

This Journal is owned, edited, and published monthly by the American Society of Agricultural Engineers.

Editorial and advertising departments at the executive office of the Society, Saint Joseph, Michigan. Publication office at Benton Harbor, Michigan.

OFFICERS AND COUNCIL
OF THE A.S.A.E.

GEO. A. RIETZ . . . . *President*
M. L. NICHOLS . . *Past-President*
J. D. LONG . . . . *Past-President*
E. D. ANDERSON . . . *Councilor*
W. W. WEIR . . . . *Councilor*
C. N. HINKLE . . . . *Councilor*
P. T. MONTFORT . . . *Councilor*
W. J. COULTAS . . . *Councilor*
HENRY GIESE . . . . *Councilor*

RAYMOND OLNEY, *Secretary-Treasurer*
RALPH A. PALMER, *Assistant Secretary*

SUBSCRIPTION PRICE: $3.00 a year, plus an extra postage charge to all countries to which the second-class postage rate does not apply; to A.S.A.E. members anywhere, $2.00 a year. Single copies (current), 30 cents each.

POST OFFICE ENTRY: Entered as second-class matter, October 28, 1933, at the post office at Benton Harbor, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 11, 1921.

The American Society of Agricultural Engineers is not responsible for statements and opinions advanced in its meetings or printed in its publications; they represent the views of the individuals to whom they are credited and are not binding on the society as a whole.

TITLE: The title AGRICULTURAL ENGINEERING is registered in the United States Patent Office.

COPYRIGHT: Copyright, 1947, by the American Society of Agricultural Engineers.

AGRICULTURAL ENGINEERING is a member of the Audit Bureau of Circulations.

Reprints may be made from this publication on condition that full credit be given AGRICULTURAL ENGINEERING and the author, and that date of publication be stated.

ADVERTISING REPRESENTATIVES

Chicago, 2: DWIGHT H. EARLY
100 North LaSalle St.
Telephone: CENtral 2181

New York, 17: A. M. WILLCOX
420 Lexington Ave.
Tele.: LEXington 2-4735

RAYMOND OLNEY
Editor and Business Manager

EDITORIAL

Rural Electric Preferred

SOME months ago it was suggested by various members that the name of "Rural Electric Division" of A.S.A.E. be changed to "Farm Electric Division".

The orderly steps of constitutional procedure have now determined, by vote of the membership, the preference of the majority, which all will recognize should govern.

Their preference is that the present name, "Rural Electric", be retained. The margin was narrow — 53 per cent of the votes of members primarily interested in rural electrification, and 57 per cent of all votes. There was no evident relation of either preference to age, area, or condition of servitude of the voters.

Some good points in favor of each name were noted on the ballots. Of these, it is most significant now that we all understand what "Rural Electric" means to the majority of agricultural engineers, and what they feel it should mean to all people concerned with the subject. In their experience and viewpoint, rural industries, rural residents, rural churches, schools and other community activities, can best be served in matters of electrification by the same electrification men who serve the farms and farmers of the same communities. They interpret "rural" to include, in addition to farms and farming, the non-farming activities of farmers and others in farming communities.

If we all understood that this is what the majority mean by "Rural Electric", whether or not we agree, the Division can continue to serve effectively and with minimum friction under its present name, until the majority finds adequate reason for a change.

Engineering in Commodity Problems

INCREASING use of a "commodity basis" of approach to agricultural problems suggests consideration of its merits in developing opportunities for effective work in agricultural engineering.

The commodity approach frankly recognizes that agricultural interests rarely are limited by the neat boundaries of any one branch of science. It provides a ready-made, distinct, and economically significant narrow field of common interest and unified objective crossing the boundaries of science. It has been found that within this clearly defined narrow field of application to one commodity, a selected group of scientists representing the several technical specialties concerned can develop effective coordination and cooperation. Each can develop some appreciation of the viewpoints, ways, means, and problems of the others. Each can let the others know what he needs from them, and what he might be able to do for them. The engineer, for example, can state his need for specific quantitive physical data on biological materials and their reactions or responses to environment. And he can give the others an indication of what he might be able to contribute in matters of manipulation, controls, operations, and power applications.

In addition to providing concrete, tangible cases and common objectives for coordination of technologies, the commodity basis focuses attention on the various "production lines" of agriculture, from propagation to consumer satisfaction. It helps to show up bottlenecks, unnecessary steps, inadequate steps, poor tooling, and other factors influencing quantity, quality, and cost of output. It helps to show what each applicable technology might do to help farmers improve their net results on their commodity production lines.

In some cases agricultural engineers have found it difficult to clarify, for the biologic, economic, and social scientists of agriculture, the engineering elements of various agricultural problems. The commodity basis of approach, emphasizing the production line sequence and interrelationships of natural phenomena and farm operations, helps to identify the engineering elements in commodity problems, and to show those who are not engineers how the net results of their work can be improved with the help of agricultural engineers.

An obvious limitation of the commodity or production line unit of study is that it does not provide for adequate consideration of the interrelationships between the various commodities and production lines. It may readily overlook, for example, crop rotation factors on the individual farm, balance of production in a community, or the economy of multiple uses for related structures and equipment. This limitation does not neutralize the advantages of commodity basis studies. Rather, it indicates that to develop fully their possibilities, further steps in intercommodity coordination and in coordination of commodity studies with other research not defined by commodity lines, are necessary.

The commodity unit of study can never be the one and only approach to the full usefulness of agricultural engineering, but it can be effective and important in helping agricultural engineers to keep their feet on the ground; and in helping to interpret agricultural engineering to those who are not engineers, in terms significant to them.

Collaboration in Research

FOR any agricultural engineer claiming more than the most casual interest in research or in the practical application of its results, and for students seeking to determine the extent of their personal interest in research, a new "must" is careful study, restudy, and frequent reference to the paper by Dr. F. A. Brooks, published elsewhere in this issue, under the title, "Research Procedures for Cooperative Projects with Limited Personnel."

It is not light reading, but it is clear correlation and evaluation of the analytical, organizational, personal, procedural, and subject-matter factors influencing the productivity of research in applied science.

Cooperative projects, in the meaning used by Dr. Brooks, are those in which there is "collaboration toward jointly recognized objectives."

Collaboration is an application of the old adage about two heads being better than one. It has proven particularly applicable in research, in its various phases of creative thought, discrimination, selection, execution, and expression, as applied to preliminary analysis, experiment, observation, and interpretation of results.

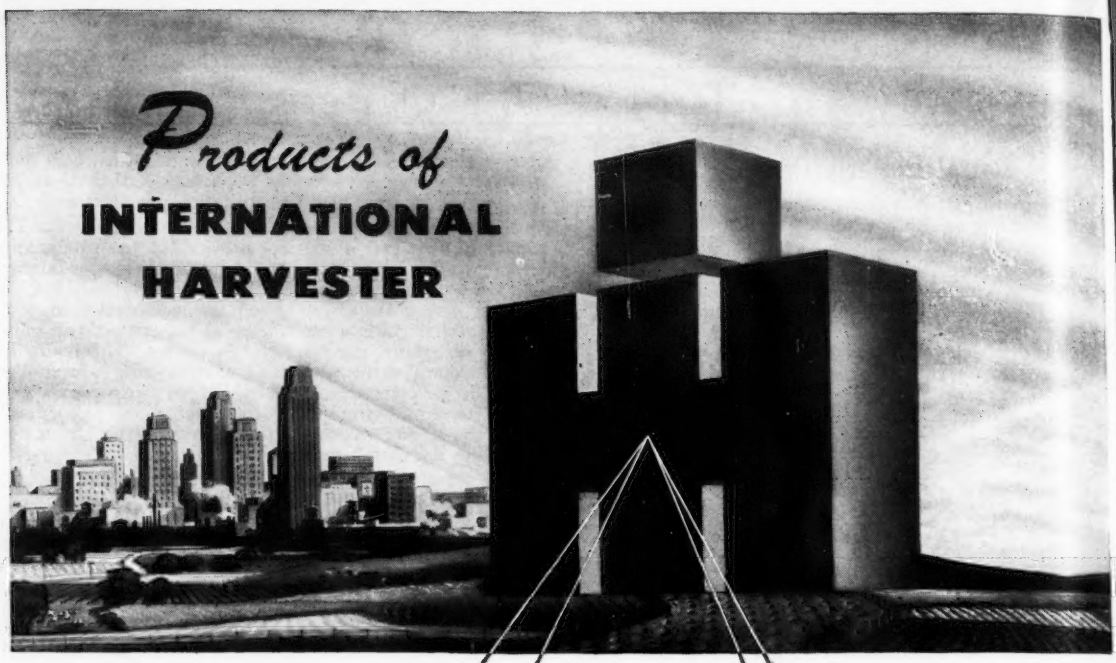
Certain mechanics of collaboration have been developed and proven effective in making the most of its advantages, while minimizing its acknowledged difficulties. They are points to be well learned, practiced, and taught to others by agricultural engineering research men and research administrators, in the interest of improved results.

It will help agricultural engineers, biological scientists, and others to arrive at "jointly recognized objectives" if we can agree with Dr. Brooks, in principle, that objectives in agricultural engineering research at present are characteristically related to our concern with the transition of agriculture from practices based on crude observations of nature to new practices depending more on scientific modification of natural conditions. The need of thoroughness and quick results in filling many gaps in the scientific foundation for such modification is obvious.

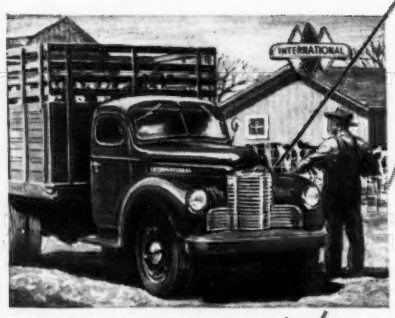
Incidentally, Dr. Brooks cites some of the techniques of research and shows how collaboration in the exercise of those techniques may contribute to valid results.

A review of some of our past research in the light of Dr. Brooks observations may be expected to reveal limitations in the value of its results.

A review of current and proposed research, in the same light, will help to classify it as to size of problem, types of personnel required, relation to other research, promising lines of approach, and prospective values.



What the International Harvester symbol means:



TRUCKS—The complete line of International Trucks offers the farm operator a wide choice of models and sizes to fit his exact needs. For more than 40 years farmers have relied on Internationals.

FARM EQUIPMENT—Farmall farming will mechanize any farm. There are 5 sizes of Farmall Tractors, with specially-designed equipment for all jobs. Illustrated: Farmall M and No. 30 Power Loader.

Products to save labor, increase production and provide better living.

A business begun 116 years ago with an important service to mankind—the invention of the reaper by Cyrus Hall McCormick.

A company dedicated, since its beginning, to the progress of agriculture, to a better way of life for the men, women and children who live and work on the six million farms of these United States.

Twenty-one plants to manufacture International Harvester farm tractors, farm machines, motor trucks, crawler tractors, industrial tractors, gasoline engines, diesel engines, and home and farm refrigeration.

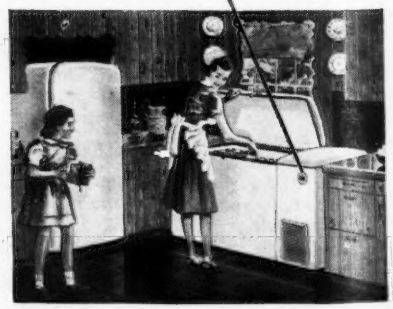
Two hundred and twelve branches and company-owned outlets, and more than 9,000 dealers, to distribute International Harvester products and to supply after-sale service.

Excellence of product now, with *greater* excellence always in preparation for the future.

INTERNATIONAL HARVESTER CO.
180 N. Michigan Ave. Chicago 1, Ill.

Tune in James Melton on "Harvest of Stars" every Sunday! NBC Network.

CRAWLER TRACTORS—Many large-scale farm operators prefer International Crawler Tractors for specialized farming. They know they can depend on them for reliable low-cost power.



REFRIGERATION—Beautifully designed, efficient . . . new International Harvester Refrigeration brings new leisure and convenience particularly to the rural homemakers of America.

AGRICULTURAL ENGINEERING

VOL. 28 OCTOBER, 1947 NO. 10

Framing Farm Buildings

By R. A. Glaze

MEMBER A.S.A.E.

WOOD has for centuries been the traditional building material for farmers. The reasons for this are so well known that it is not necessary to cite them. Still, with generations of experience in the construction of frame buildings behind us, we frequently make mistakes and misuse our most valuable building material. Lumber *is* an engineering material and is recognized as such by structural engineers. It did a magnificent job during the war. We learned a lot about right and wrong ways of using it. I would like to sum up some of the lessons learned that can be applied to correct and economical framing of farm buildings. Correct usage of lumber will result in more permanent, more satisfactory, and more economical buildings.

HISTORY OF JOINTS

The efficiency of wood as a structural material has kept pace with but has also been limited by the development of fastenings. Perhaps the first wood fastenings were made by some prehistoric man who bent saplings together and tied them with a withe or strip of bark to form the framework for his home. In doing so he produced an arched roof structure. Arches are still used today because of their efficiency. When he wanted a more complicated joint, it is natural that being a hunter, he would turn to the animals that furnished him with food and clothing and used a leather thong to fasten the head to the handle of his axe or spear, or to bind together the framework of his tepee, as the Indians did in even more recent times.

Wooden Pins. The use of wood pins had its origin in the wooded sections of middle and northern Europe, and it was not until quite recently that spikes were available. The use of wood pins was practiced until well after the turn of the last century. Many barns and other structures are still standing today in which the sills, girts, rafters and tie beams are pinned together with heavy wood pins.

Nails. The origin of nails has been lost in antiquity although they are mentioned in the Bible in connection with the building of Solomon's temple about a thousand years before Jesus. More familiar, of course, is the reference to their use in the Crucifixion. Nails were scarce and had to be made by hand until about 1800, when cut iron nails came into production. Steel wire nails, as we now know them, were first made in France about 1840, but were not produced in this country until about 1875. The rapid western expansion of our country perhaps could not have been possible had it not been for a plentiful supply of nails and lumber with which to build homes, farm buildings, schools, factories, churches, and railroads. Of course, all fences were wood, and so were even the sidewalks. Paralleling the development of nail production from crude iron nails hammer-

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Farm Structures Division.

R. A. GLAZE is chief engineer, Weyerhaeuser Sales Company.

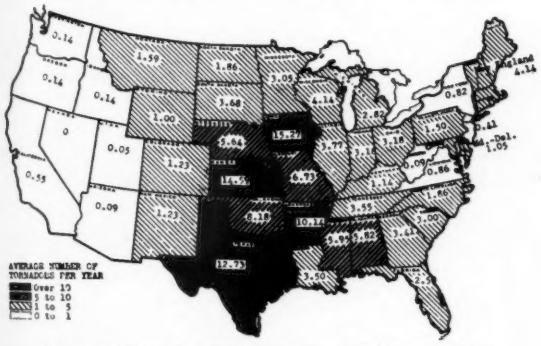
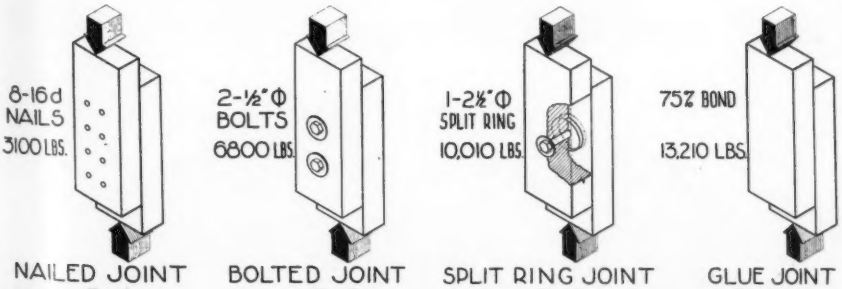
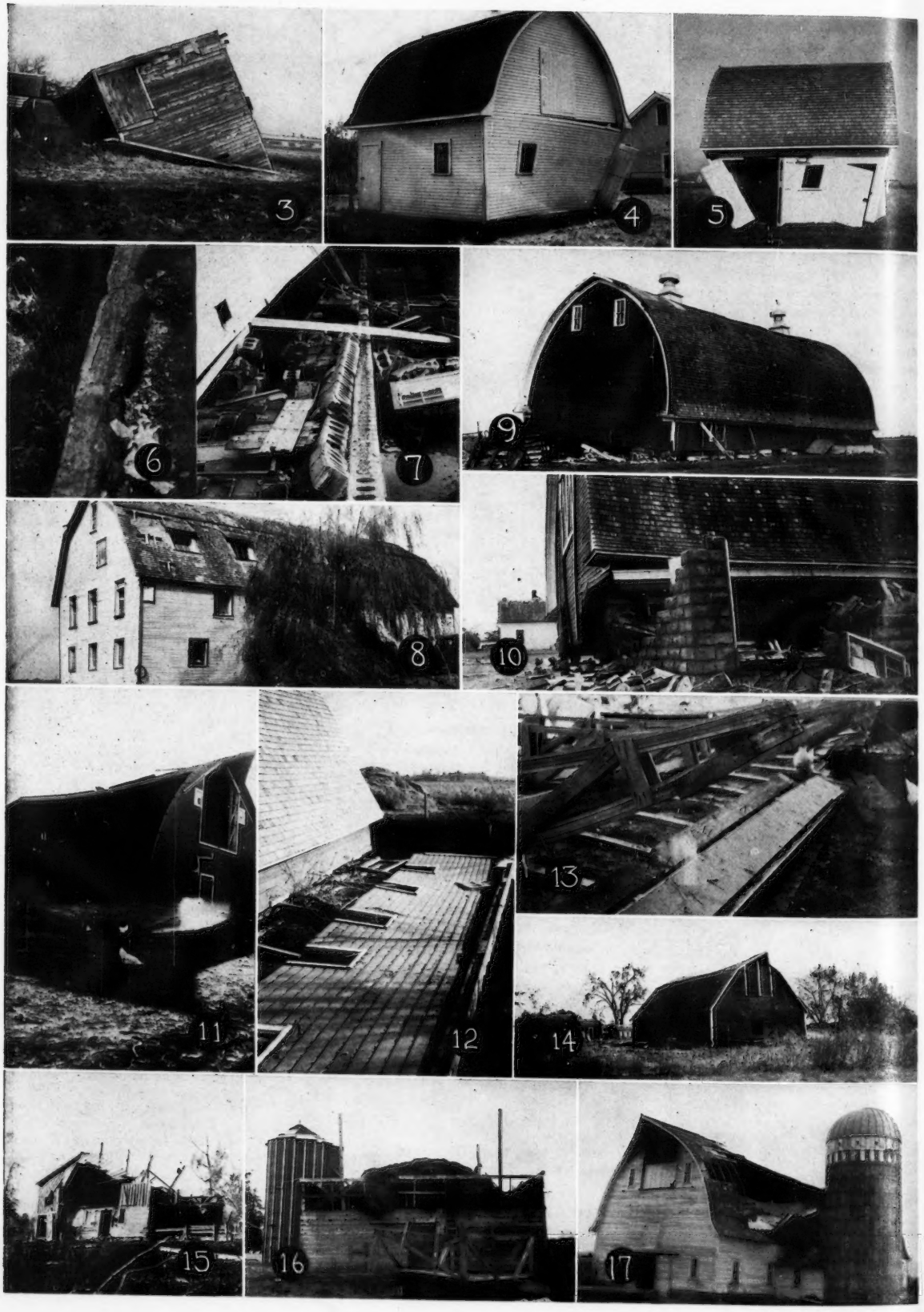


Fig. 1 Number of tornadoes per year by climatic sections (average, 1916-1937)

TABLE 1. PROPERTY DAMAGE PER YEAR CAUSED BY TORNADOES (Average, 1916-1937)

Missouri	$1,494,675	Pennsylvania	$125,477
Illinois	1,358,300	South Dakota	91,414
Georgia	929,568	New England	83,827
Ohio	859,915	Maryland-Delaware	59,474
Texas	642,584	New York	55,305
Iowa	578,847	New Jersey	52,659
Indiana	559,289	Virginia	49,000
Kansas	555,532	North Dakota	39,227
Minnesota	545,882	Florida	35,337
Alabama	495,645	Colorado	28,173
Mississippi	446,875	Wyoming	18,244
Oklahoma	437,423	New Mexico	13,814
Arkansas	414,345	California	12,977
Wisconsin	353,082	Montana	8,569
Michigan	310,066	West Virginia	1,364
Tennessee	254,127	Oregon	482
Kentucky	222,205	Idaho	182
South Carolina	219,852	Arizona	114
Nebraska	216,400	Washington	11
Louisiana	200,127	Utah	Slight
North Carolina	147,150	Nevada	None




3
4
5
6
7
9
8
10
11
12
13
14
15
16
17

ed out one at a time, to the perfect machine-produced modern product, is the development of modern sawmilling practices which gave us light dimension lumber. These two developments enabled our fathers to improve upon the heavy, European-born post-and-girt timber-type of construction, and to develop our modern light stud-and-joist system.

Bolts. Bolted structures have been efficiently carrying loads for 150 years, even though the wood members have had to be made greatly oversize in order to develop the bolt strength at the joints. Wood was used mainly for compression members because an efficient, practical tension joint for wood was not available.

Modern Timber Connectors. After the first World War, the French had control of much of Germany's ore supply, and Germany, as an economic necessity, turned to timber construction. Since the timber available was of relatively small size, it became more important than ever to develop efficient structural fastenings. From this necessity came modern timber connectors.

When first introduced into this country about 1930, they were heralded as the greatest contribution to wood construction in 300 years, as indeed they were. Their use increased the strength of joints from two to six times and made tension members practical. These fastenings made possible the economical erection of timber structures that had not been feasible under previous methods of framing. They opened up to us a whole new field in the use of wood as a structural material. Timber connectors are simply metal dowels of one form or another which are used in the contact faces of lapped framing members to reinforce the joints in resisting shear. We have sufficient technical information at hand to enable us to use timber connectors with assurance. There are many places in and around farm buildings wherein timber connectors would materially stiffen and strengthen the joints.

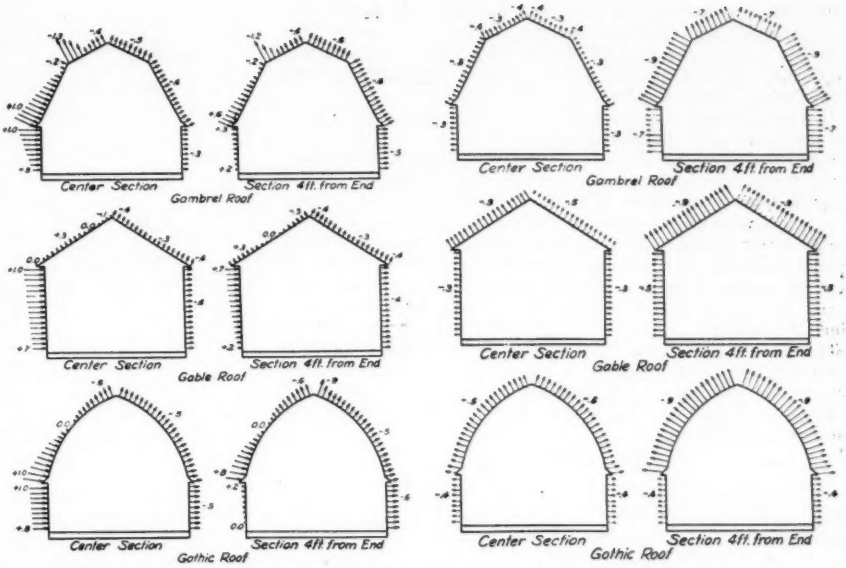


Fig. 18 *(Left)* Sections of three models showing forces due to wind perpendicular to side, all doors closed • Fig. 19 *(Right)* Sections of three models showing forces due to wind perpendicular to end, all doors open. (Diagrams reproduced from Kansas State College Bulletin No. 42, entitled "The Design of Barns to Withstand Wind," by F. C. Fenton and C. K. Otis)

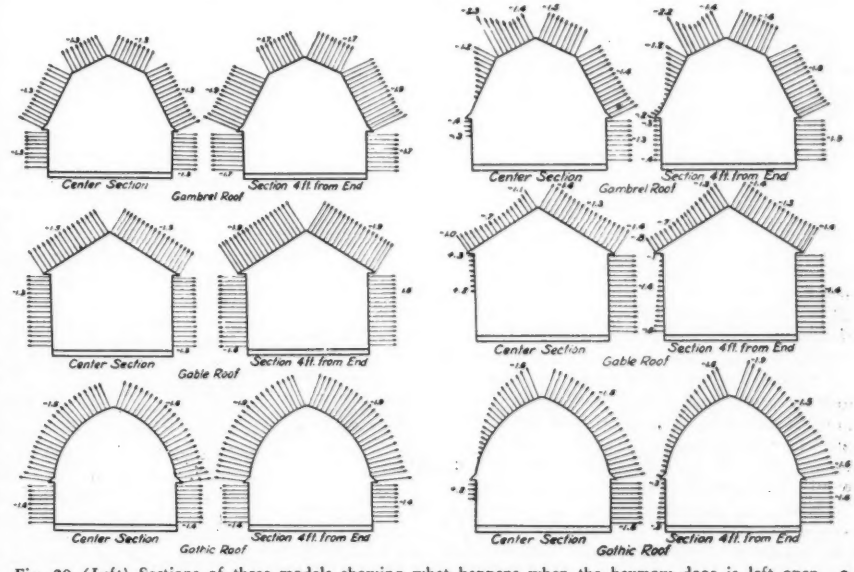


Fig. 20 *(Left)* Sections of three models showing what happens when the haymow door is left open • Fig. 21 *(Right)* Sections of three models showing forces when a large side door is left open. (Diagrams reproduced from Kansas State College Bulletin No. 42, entitled "The Design of Barns to Withstand Wind," by F. C. Fenton and C. K. Otis)

Glue. As important as was the advent of timber connectors, we are now entering a whole new era in wood construction made possible by the recent developments in glues and gluing techniques. These new glues make it possible for us to "weld" lumber together in width, length, and thickness. Of most importance to agricultural engineers are glued laminated structural units—timbers—made up of ordinary boards glued face to face with water-resistant glues. Great structural efficiency is obtained because we can forcibly bend the individual plies to an efficient arch shape while gluing. These shapes are difficult to obtain with solid timbers, and *laminated* arches have the added advantage that the grain of the wood follows the line of principal stress.

RELATIVE STRENGTH OF DIFFERENT FASTENINGS

The most common joint used today is the simple nailed joint. Fig. A is an example of a shear test made on a nailed joint. Two pieces of 2x6 fastened together with eight 16d spikes carried a load of 3,100 lb. Fig. B shows that two pieces of 2x4 bolted together with two ½-in bolts carried 6,800 lb, more than twice as much, and needed one-third less material. The timber connectored joint, Fig. C, with one 2½-in diameter ring embedded between two 2x4's carried 10,010 lb. From this we can see that a ½-in bolt is as good as six to ten 10d spikes,

and one 2½-in connector is as good as about six ½-in bolts, but it would be impossible to put six bolts at the intersection of two pieces of a 2x4 as can be done with the connector. Split-ring connectored joints will make use of as much as 80 per cent of the tensile strength of the wood.

Fig. D shows a glued joint wherein two pieces of 2x4 are lapped 8 in and glued together with a phenolic resin adhesive and ordinary C clamps. This joint was tested to failure, and upon examination showed about a 75 per cent coverage of the contact faces. Even so, this joint carried 13,210 lb.

A properly made glued joint is actually stronger than the wood fibers themselves. Do you wonder that we foresee great possibilities in structural combinations of glue and wood? I do not mean to predict that the carpenter of tomorrow will carry a glue pot and brush instead of a hammer and nails, but Henry Giese (professor of agricultural engineering, Iowa State College) and others have demonstrated the possibility of reinforcing our ordinary nailed joints with glue. We do know that glued laminated framing, factory fabricated under controlled conditions, will enable us to build more rapidly and economically.

FARM BARN FAILURES

Even though we claim to know a lot about barn construction, nowhere is there so much evidence of abuse of good building materials, both lumber and masonry, as we see in barns. In an attempt to profit by the mistakes of the past, several of us made an inspection tour through a wind-swept area in 1942, wherein more than a thousand barns were destroyed. This wind was of rather steady velocity but was not excessive. It would not be classed as a hurricane. The velocities were in the neighborhood of 55 to 70 mph. One of the unusual features was the fact that the wind did not excessively damage other so-called permanent structures. Barns and large farm buildings were damaged, but houses and smaller structures were not destroyed. There is no reason why barns could not and should not be built to withstand winds that do not damage other permanent buildings. A check-up of the causes of barn failures leads us to several distinct conclusions.

The accompanying illustrations (Figs. 3 to 17) show some of the many contributing factors, but first, let us look at some facts about wind.

Fig. 1 shows the number of tornadoes per year. We usually think of Kansas and Nebraska as being among the windiest states, but notice that Iowa has more tornadoes than either Kansas or Nebraska. Ohio and Indiana have more than Minnesota. The eastern states do not have as frequent tornadoes. Nevertheless they do have some.

Table 1 shows the property damage per year caused by tornadoes. Missouri has the highest property damage, but most of our good farming states are well up. Perhaps some of the property damage could be traced to lower quality of construction in certain areas. Maybe Pennsylvania losses would be higher if they did not build so well.

The most common reasons for barn failures are (1) the nature of wind pressure, (2) method of making certain joints, (3) masonry block foundation failures, and (4) anchorage failures.

Fig. 3 shows a grain bin which failed because of total lack of anchorage. This building was merely sitting on some rocks.

Figs. 4, 5, and 6 illustrate what happens when poor concrete is used. The foundation wall was of such poor quality that the anchor bolts pulled out, permitting this well-built little barn to be twisted out of shape.

Fig. 7 shows the failure of a masonry block foundation. Masonry block walls are only as strong as their weakest mortar joint. Most building codes would not permit unbuttressed walls of this length, yet we do not hesitate to build long barns without bracing the walls either by cross partitions or with buttresses.

Fig. 8 shows a relatively undamaged older barn that was securely anchored to a monolithic concrete foundation. This building was only a few yards from the one shown in Fig. 7, and suffered the loss of but a few shingles.

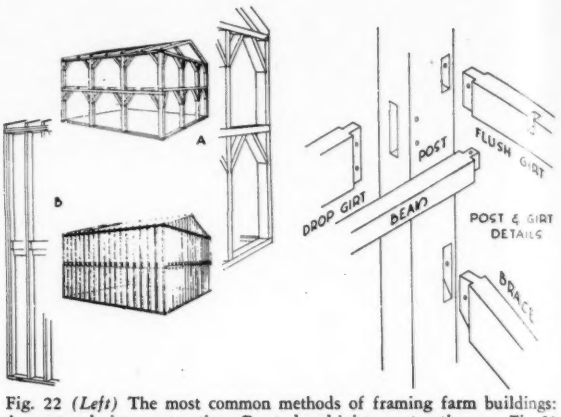


Fig. 22 *(Left)* The most common methods of framing farm buildings: A, post-and-girt construction; B, stud-and-joist construction • Fig. 23 *(Right)* A few typical details of post-and-girt construction found in many farm buildings

Figs. 9 and 10 illustrate another block foundation failure. The superstructure was moved sideways a distance of the post height and suffered very little damage. The foundation was a total loss. Twenty-one cows and two horses were killed. Four calves were unhurt. The calf pen was located in a corner of the barn. The corner served as a buttress which did not fall in. Fig. 10 shows the corner still standing.

Figs. 11, 12, and 13 are of a barn that was well built of far more material than we usually use. However, the principal joints were merely toenailed. Complete failure occurred at the sill, plate, and ridge. The leeward half was lifted completely out but was not too badly damaged. One unusual point is that the windward side of the mow roof still remained standing.

Fig. 14 shows the mow structure left standing but with the stable portion gone. This is a failure of the sill and plate joints. Figs. 15 and 16 show what happened to old heavy timber frame barns. The mows of these buildings were usually so badly destroyed that it was difficult to tell wherein the failure lay. There were so many of this type of failure that we soon grew tired of photographing them.

Barns Do Not Blow Down. After carefully analyzing what we saw in the field survey of wind damaged barns, (Fig. 17), we came to the conclusion that barns do not blow down in a windstorm. The next group of illustrations (Figs. 18 to 21) will show why. These were taken from Kansas State College Bulletin No. 42, "The Design of Barns to Withstand Wind" by F. C. Fenton and C. K. Otis. They show the results of wind tunnel tests on models of farm buildings.

In Fig. 18, the arrows show the direction and magnitude of the forces due to the wind. In this case, the wind is perpendicular to the left side. All of the doors are closed. Note that pressure on the building changes to suction or lift about two-thirds of the way up the roof. The result of these forces would be a very definite upward lift on the leeward side.

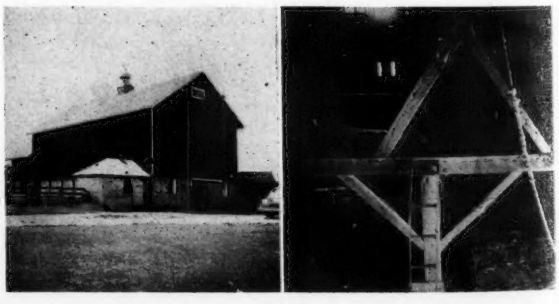


Fig. 24 *(Left)* and Fig. 25 *(Right)* A typical example of heavy timber framing

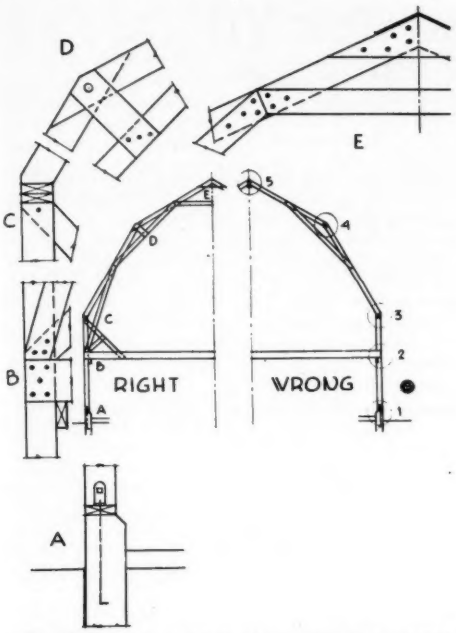


Fig. 26 This drawing shows details for improving stud-and-joist framing

Fig. 19 shows the forces due to the wind perpendicular to one end. Notice here that all of the force is upward and outward.

Fig. 20 shows what happens when the haymow door is left open. Notice how the magnitude of the forces is greatly increased.

Fig. 21 shows forces when a large side door is left open. The loading here is definitely eccentric and would most certainly tend to lift the structure.

Thus we can see how important it is to tie our buildings *down. Barns never blow down; they blow up.*

WHAT TO DO ABOUT IT

Coming now to the most common methods of barn framing. Fig. 22 shows the post-and-girt system at A. This is a method of construction that was introduced in this country by the early colonists. It was the most convenient method of framing for them because the timber had to be hand hewn. Basically it consisted of heavy posts spaced well apart, tied together with girts, and braced with knee braces. Early buildings of this construction use no nails or metal fastenings of any kind. Members were mortised and doweled together. In this method of construction, all of the strength and rigidity of the structure were found in the framing. The weather boarding or curtain wall between the posts was completely non-structural and consisted of vertical boards and battens, brick, stone, or wattle and daub.

The stud-and-joist system illustrated at B is our present very efficient method of construction made possible by the availability of small dimension lumber and a plentiful supply of nails. It consists of small members spaced closely together and braced by the sheathing or skin covering of the building. Practically all of our residences are now framed in this manner. It is the most efficient method of building yet developed because all parts serve a structural as well as a weather-resisting purpose. We hear much comment about the inefficiencies of modern building methods, but it would be difficult to improve upon this system of construction developed through years of evolution. Most of our systems of pre-fabrication use the stud-and-joist type of construction. Laminated arched buildings are one more step in the improvement of the stud-and-joist type of construction. Studs and rafters are combined in one continuous member, thus eliminating many jointing problems.

Fig. 23 shows a few typical details of post-and-girt construction commonly found in many farm buildings. Notice the amount of material cut away to provide tenons. A girt or a beam is only as strong as the tenon. A tie beam in tension would be only as good as the pins holding it in place. In many cases, a couple of strands of No. 12 wire would give the same result as an 8x8 40 ft long, common in many barns.

Figs. 24 and 25 shows a 50-year-old Wisconsin barn which is a typical example of heavy timber framing. All of the joints are mortised, tenoned, and pinned.

In Fig. 26, as good as is the stud-and-joist system of framing, its use in large barns could be materially improved by following one or two very simple rules. As we discovered in studying wind-damaged buildings, the most common points of failure were the sill, plate, and ridge, wherever toenailing was used. In order to eliminate toenailing it is always wise to lap members past one another and put nails, bolts, or fastenings in shear. The ridge joint may be further reinforced by a light strap iron over the rafter junction.

Fig. 27 shows one or two suggestions for improving toenailed joints. Clip angles are commonly used and are furnished with large laminated arches. A metal or plywood gusset plate, if it does not interfere with the sheathing, would help to tie the framework down. Strap irons can be used in many ways. All of these suggestions are merely expedients.

Perhaps the best way of all would be to use the Timber Engineering Company's newly developed Trip-L-Grip anchors shown in Fig. 28. These are a series of pressed-metal devices than can be used in a great many places. They serve to develop the full strength of the nails in shear and eliminate the uncertainties of toenailing. Three types are made, all in right and left-hand patterns to meet nearly any requirement. Rural builders will find them most useful in fastening studs to sills and plates, rafters to plates, girts to posts and beams to girders. Many recently built grain bins and corn cribs have used the Trip-L-Grip anchors as stud sockets to resist the lateral thrusts at the sill as well as reinforcing for the joists and rafters.

In conclusion I would like to emphasize that our present systems of building are practical and efficient. Timber *is* as much of an engineering material as are other common building products. Attention to small details will improve the construction of even large buildings and make them more resistant to wind stresses without increasing the cost.

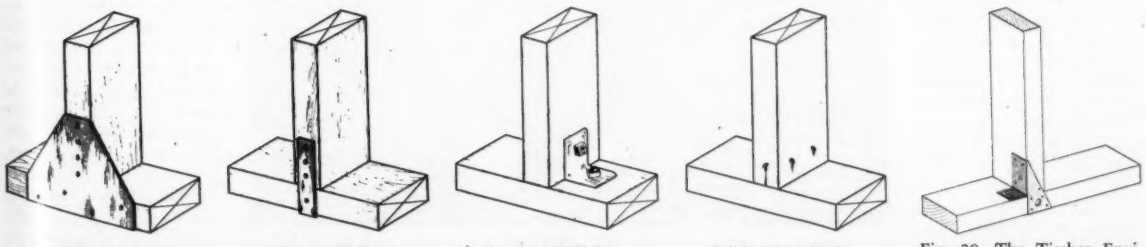


Fig. 27 This drawing shows three suggestions for improving toenailed joints

Fig. 28 The Timber Engineering Company's newly developed Trip-L-Grip anchors

Soil Erosion Studies—Part VII

SOIL TRANSPORTATION BY SURFACE FLOW

By W. D. Ellison and O. T. Ellison
MEMBER A.S.A.E.

FLOWING surface water is usually the major transporting agent when erosion is caused by a rainstorm. This flow may move across the land in several forms. First, it may move across broad surfaces that have no perceptible channels, as a shallow sheet of water, in which case it is referred to as sheet flow, or prechannel flow. Second, it may move in rills, gullies, or valley channels, in which case it is referred to as rill or gully flow, or merely as channelized flow.

When broad sheets of water move across open fields in prechannel stages during rainstorms, velocities of translation will seldom develop sufficient soil suspending capacity to move appreciably large amounts of soil. It is the energy of turbulence imparted to this flow by splashing raindrops that gives it much of its suspending capacity. The same is true of many shallow channelized flows, and raindrops bombarding these water surfaces may often increase their transporting capacities by several hundred per cent.

The kinetic energy imparted to shallow surface water by impact of raindrops not only increases the transporting capacity of flowing water, but it may give to standing water a soil-suspending capacity. Standing water that is being churned by splashing raindrops has been found to contain as high as 20 per cent of soil. This soil content is affected but little, if any, by velocity when the standing water starts to flow, so long as it moves across smooth surfaces as sheet flow.

The soil transporting capacity that is imparted to shallow surface water by splashing raindrops will vary widely with sizes of drops and velocities of their impacts. Under certain conditions the turbulence imparted by splashing raindrops may cause much coarse sand and some small gravel to be moved by surface water that is barely flowing. These movements were described in a previous paper[1], and the following is quoted from a note that was made while observing erosion on a small plot that was free of rills and gullies: "It was observed that raindrop impacts, under certain conditions, would move stones as large as 10 mm in diameter when they were partially or wholly submerged in water. When raindrops would strike these submerged stones, the stones would rise and frequently they would move some distance downslope. Where there was surface flow, this would assist the downhill motion even though the surface flow acting alone would not move them."

More recent observations by the authors have further demonstrated some outstanding effects of splashing raindrops on the transporting capacities of prechannel flow. In these it was observed that soil-bearing water flowing more than one-half inch deep and more than one-quarter foot per second deposited soil on a city pavement each place where it flowed under a parked automobile. The flow was not highly charged with soil, but under each car there was left a deposit which fully covered the concrete. Each of these deposits conformed in every detail to the shape of the protection afforded by the car above it. Between the parked cars, where splashing raindrops continued to churn the flow, there were no deposits whatever.

Splashing raindrops may also greatly increase the transporting capacity of shallow channelized flow. Many of us have observed this at the lower ends of runoff plots. When the runoff leaving such a plot is high in silt content, an intercepting trough along the lower edge may fill very quickly with soil if it is covered to keep out falling raindrops. By removing the cover from this trough so that raindrops can strike the surface of the flow, one may not only prevent further deposits, but deposits already in the trough may also be removed.

There can be no doubt that splashing raindrops have a major effect on transportation of topsoil from a field. If the surface of a field is fully protected against the impact of raindrops, there will be very little soil transported except that which is detached and moved by channelized flow. In such cases the topsoil between the rills and gullies may remain practically unimpaired throughout the storm. These facts help to establish the outstanding need we now find for some improved types of transportation experiments; experiments in which raindrops are applied to shallow surface flow while testing and evaluating the principal transportation factors that operate on field surfaces between gullies and channels during rainstorms. Fig. 1 shows a field where soil erosion occurs both within gullies and on smooth surfaces of the field between gullies. Much of the soil lost from between these gullies must be transported in prechannel stages of flow.

Some Important Relationships of Transportation Factors. It is usually the transportation process that tends to make soil loss per unit of area decrease with each increase in slope length. If a slope is only 4 ft long, then an average of only 2 lb-ft of soil transportation is necessary to remove each pound of soil from the slope. But if the slope length is 400 ft, an average of 200 lb-ft of transportation, or 100 times as much as on a 4-ft slope, is required to remove each pound of soil.

This increase in energy requirements for transporting eroded soil, as the slope length increases, will usually be more than offset by water concentration within gullies. Outside the gullies, however, no such water concentrations occur, and soil loss per unit of area will usually decrease with each increase in slope length.

Fig. 1 Soil transportation in these gullies is by channelized flow. Between the gullies the soil is transported in prechannel stages and splashing raindrops will impart to this shallow water a high soil-suspending capacity

This paper was prepared expressly for AGRICULTURAL ENGINEERING, and is the seventh of a series. The eighth and concluding paper will appear in an early issue.

W. D. ELLISON is assistant chief, division of drainage and water control (research), Soil Conservation Service, U. S. Department of Agriculture.

O. T. ELLISON is a student in agricultural engineering.

[1]Studies of Raindrop Erosion, AGRICULTURAL ENGINEERING, April and May, 1944, vol. 25, nos. 4 and 5, pp. 131-136 and 181-182.

There is still another aspect of the transportation problem that operates to cause soil loss per unit of area to decrease with increases in slope length. This is the matter of soil in transport when the rain ceases. If equal amounts of soil were removed from each unit of area throughout the full length of a slope, and if the flow was of uniform velocity from hilltop to valley bottom, then the soil in transport at the time rainfall ceased would tend to be related to slope length L in the order of $L/2\ (L+1)$, or $(L^2+L)/2$. Even though the soil removed from each unit of slope is seldom uniform from top to bottom of a hill, yet the total amounts of soil in transport at the time rainfall ceases will usually represent an increased volume per acre each time slope length is increased. Since transportation on field surfaces almost ceases when raindrops stop falling, the amounts of detached soil in suspension, and which may be deposited at the termination of rainfall, will increase as the slope length is increased.

Both of the above factors will operate to cause soil loss from a field to vary inversely as the slope length, or as L^{-x}. This relationship causes subsoil to appear first through the topsoil near hilltops, and soil loss per unit of area is then greatest on the shortest slopes. Gully erosion tends to reverse these relationships, but where gully erosion is not highly active the transportation process will tend to cause a decrease in soil loss per unit of area each time the slope length is increased. Transportability of the soil will have a pronounced effect on these relationships, and this aspect of the problem will be discussed in a later paragraph.

It seems quite obvious that the transportation factor must be evaluated in foot-pounds, but an example might help to clarify this matter further. For this example, let us assume we are studying a sloping area 200 ft square, and that there are 2,000,000 lb of topsoil on the slope. Soil from the upper edge will have to be transported 200 ft downslope to be carried off. Soil from the lower edge will be lost just as soon as it is set in motion. The *average* distance of transportation will be 100 ft. When there has been 2,000,000 lb of soil transported an average distance of 100 ft, or 200,000,000 lb-ft of downslope transportation, there will be no topsoil left.

The amounts of soil transportation on a field cannot be measured in many instances. However, the transportation hazard can be evaluated and the transportation that actually occurs will be proportional to this hazard. Therefore, by estimating transportation hazards, one may then estimate soil inventories for any future date. By manipulating or regulating these hazards through erosion control practices, one also regulates the decreases that will occur in future inventories. The basic transportation hazard is proportional to the transportability of a soil and the capacity of the transporting agent. The equation for determining this hazard is

$$T'_1 = f(T'_2, T'_3) \qquad [1]$$

Where T'_1 = the pounds-feet of soil transportation, or the transportation hazard that exists on a bare, open field

T'_2 = the transportability of the soil

T'_3 = the transporting capacity of the surface flow.

Experimental work is needed to determine values of T'_2 and T'_3 that will apply to different fields, and this work must be so organized as to provide for manipulating each as an independent variable. Let us now examine T'_2 and T'_3, and determine their important component parts. The breadth of application of our results, and their practicability, will be enhanced by identifying and evaluating all the important factors that compose the T'_2 and T'_3 variables.

Transportability of the Soil (T'_2). The transportability of a soil particle in flowing surface water will depend largely on its shape, density, and size.

Shape will be important when particles are so large and dense that they are transported by a process of rolling over the surface. Projecting corners and broad flat sides will prevent their rolling as freely as will round-shaped particles.

The factor of density will affect the suspension process, and consequently the settling rate of a particle that has been set in motion in the surface flow.

The distances that particles are floated each time they are splashed into suspension is a function of their rates of settling. This suggests that rates of settling of soil materials may be used as an index of their transportability. This aspect of the problem must be explored. But in addition to a study of settling rates, we are in need of some experiments that will employ surface flows that are stirred by splashing raindrops, to determine the relative transportabilities of different soil materials under conditions of field performance. It seems probable that the results obtained in these experiments can be referenced to settling rates of different soils, and if this proves to be a practicable procedure, the problem of determining a soil's transportability may then be solved by determining the settling rates of its aggregates and unaggregated particles.

Particle size affects its total weight, and variations in this factor may be most important when the flow is so shallow that it approaches a depth equal to the diameter of the particles in transport[2]. However, it is questionable if the depth-diameter-transportability relationship discovered by Lutz and Hargrove will always apply to flow that is bombarded by raindrops.

A change in the state of a soil's aggregation may cause a change in each of the three factors of shape, density, and size. Usually an improvement in the state of a soil's aggregation will make the particles less transportable. But there can be combinations of circumstances where increased aggregation of certain soils may increase their transportabilities.

Since the transportability of a soil will vary with its state of aggregation, it is important to use aggregated soils in experiments where a soil's transportability is to be evaluated. If there are significant differences in the state of aggregation of a particular soil, either differences from point to point on a field, or differences from one season to another, it will be important to test these differences. Usually it will be found that soil materials at tops of slopes differ in their transportabilities from those at bottoms of slopes; and there may be other locations on fields where soil aggregation will be expected to vary.

The material at the base of a sand slope tends to be more transportable than that near the top of the slope. This is caused by a process of selective erosion which causes fine sands to be moved downhill at a faster rate than are the coarser materials, thus leaving the coarser and less transportable materials high on the slope. This phenomenon will be most apparent in early stages of erosion, and many striking examples of it are to be found on the Kirvin sands of Texas. Of course, on the very crest of the hill, where the slopes are less steep, very little of the fine sands may be washed out. But farther down, on the upper portions of the steep slopes, most of the fine sands may be missing. One would expect that after many years of unchecked erosion, the coarse sands too may be carried downslope.

On clay soils the above-mentioned conditions are usually reversed. That is, materials at the base of a clay slope are usually less transportable than are materials higher on the hillside. This is largely caused by selective transportation. On these soils the erosion process may leave no heavy materials behind. But when deposits occur near the base of the hill they include a high percentage of the materials that are of low transportability, while the clay fractions and other very light materials may float far beyond the base of the slope.

It seems unnecessary to introduce a standard soil when testing a soil's transportability in surface flow. It should suffice to standardize the capacity of the transporting agent and the surface over which the soils are transported. It is believed that after these two factors have been standardized, along with the method of injecting the soil into the water, that the pounds-feet of soil transportation can be used without conversion, as representing the relative transportability of a soil.

The standard surface on which these tests are made should not be smooth. It is believed that a roofing paper that is covered with coarse sand or pebbles will suffice. It is essential that it be a surface that will (1) be easily duplicated, (2) be

[2] Soil Movement as Affected by Slope, Discharge, Depth and Velocity of Water, by J. F. Lutz and B. D. Hargrove. Tech. Bul. No. 78, N. C. Agri. Exp. Sta., January, 1944.

similar to a soil surface, and (3) permit recovering all of the transported material at the points of deposit.

As for standardizing the transporting agent, it will be necessary to use surface flow bombarded by raindrops. This produces an entirely different result from that obtained when surface flow only (without raindrops) is applied. Of course if we wish to test transportation in deep channels, the raindrops may not be necessary. But on open field surfaces, practically all of the transportation outside the gullies occurs under the influence of falling raindrops, and these drops often increase the amount of transportation by several hundred, or even several thousand per cent.

It was previously stated that the transportation factor is the primary cause for decreases in soil loss per unit of area, that are associated with increases in slope length. One important element of the transportation factor that limits these losses is soil transportability. Decreases resulting from increases in slope length will tend to be greatest on soils of low transportability, and least on soils of high transportability. If the soil particles are of such low transportability that they are moved only intermittently, by being bounced, dragged, or rolled only a short distance each time they are set in motion, there may be sharp reductions in soil loss per unit area each time slope length is increased. But if the soil is of such high transportability that practically all of the eroded materials are carried along in continuous suspension, there may be little or no decrease in soil loss when slope length is increased.

The transportability of a soil will also have definite relationships to degree of slope. For example, if a soil is so highly transportable that it is carried in almost continuous suspension, practically all of the soil that is detached may be transported on very gentle slopes, and further increases in slope may have but little or no effect at all on soil losses. But if a soil is of very low transportability, such that many of its particles must be dragged and rolled along over the surface, each increase in slope may cause considerable increase in the soil loss.

Soil transportability will also have a bearing on the effectiveness of various erosion control practices. If a soil is so highly transportable that it is carried in almost continuous suspension, small ridges, depressions, and small straws and stems of plants on the surface will impede soil movements but very little. But if a soil is of very low transportability, these surface irregularities may greatly retard soil transportation processes. Soil transportability must be determined before we can fully interpret soil loss measurements and design most effective erosion control practices to check these losses.

While the matter of extending soil loss data by extrapolations from plots to large fields concerns more than the scope of this paper, yet this point in our discussion seems an opportune time to mention the effects of the transportation process on this problem. If a runoff plot from which soil loss is measured is very short, the transportation factor is minimum and detachability of the soil may limit rates of soil loss. This fact was recognized in selecting a round plot of 3-in diameter to measure soil detachability[3]. As plot length is increased, a length may be reached at which the transportation factor becomes the control that limits soil loss. The length at which the control may shift from detachment to transportation will depend very much on soil transportability. If the soil is of low transportability, the shift will occur on much shorter slopes than if it is of high transportability. Certainly one cannot extrapolate from short plots where detachment factors limit losses, to large field slopes where transportation factors limit these losses.

Soil transportabilities may affect exposures of subsoils on hillsides. If the subsoil on one hillside is exposed much farther downslope than that on another hillside of equal slope, and if the two have received like use and treatment, the one with subsoils appearing lowest on the hillside may be assumed to have the most highly transportable soils.

Transporting Capacity of Surface Flow (T'_3). The soil-transporting capacity of unit width of surface flow will depend upon three principal factors: (1) the velocity of translation which controls the velocity at which the materials in suspension are moved across the surface, (2) the depth of the flow, as the product of this and velocity will determine the volume of flow per unit of width, and (3) the capacity of the flow to suspend soil materials, as this factor will limit the soil content of the flow.

If the energy gradient of the translational velocity is designated as $V^2/2g$, the depth as d, and the factor of turbulence as D_3 (because it will be proportional to D_3[3]), then the transporting capacity of the surface flow (T'_3) may be expressed as follows:

$$T'_3 = f(V^2/2g,\ d,\ D_3) \qquad [2]$$

Where $V^2/2g$ = the energy gradient of the velocity of translation

d = the depth of the flow

D_3 = the capacity of the falling raindrops to impart turbulence to the surface flow (this will be proportional to its capacity to hold soil materials in suspension).

If one were testing the transporting capacity of water applied as surface flow in flood irrigation work, the splashing raindrops would not be introduced, but the entire amount of water used would then be applied at the top of the slope. This irrigation problem is not a part of this paper, but the distinction between flow of irrigation water and storm flow must be recognized. Also, one must keep in mind that when the erosion is caused by a rainstorm, practically all of the soil transportation outside the gullies occurs during rainfall, with raindrops and drip from plants bombarding the surface of the flow.

The transporting capacity of a flow that is being bombarded by falling raindrops is not to be confused with the transporting capacity of raindrop splashes. We have recognized that the splashes will transport particles through the air just as chips of stone may fly through the air when one strikes a rock with a hammer. However, when the raindrops work through surface water to splash soil particles, they will impart to the surface water considerable amounts of energy. The effects of this energy transfer is the factor included in this phase of the work by introducing the D_3 factor.

In transportation experiments the T'_3 factor may be held constant for any one experiment or for a group of experiments by regulating the release of flow at the upper end of a plot and by regulating the release of raindrops from above the path of the flowing water. In the course of a series of experiments designed to evaluate T'_3, each of the factors of $V^2/2g$, d, and D_3 must be manipulated as independent variables that are held constant for the duration of an experiment.

On soils that are of very low detachability and very high transportability, an increase in the transporting capacity of surface flow may cause little if any change in soil tonnage loss from a field's slopes. But on soils of high detachability and low transportability, an increase in the transporting capacity is almost certain to increase tonnage losses. As a result of this, we may assume that erosion control measures which reduce the transporting capacity of surface flow will be most effective in reducing tonnage losses from those fields having least transportable soils, and least effective on those fields having most highly transportable soils.

Other Factors Affecting Soil Transportation. Most of the factors that affect the transporting capacity of surface flow will do so through their effects on the energy factors. Because of this, they will be accounted for by adjusting the energy values of $V^2/2g$, or D_3 that are employed in equation [2]. These effects on the energy factors are caused by such things as stems of plants that retard velocities, increases in slope or channel elements that increase velocities, contour ridges, and terraces that divert and dams that impound water and thereby reduce the flow energy.

But there are two factors which in addition to their indirect effects through changing flow energy will also have a direct influence on movements of soil. These are (1) slope and (2) irregularities in the surface. It was stated in a previous paragraph that these factors will (Continued on page 450)

[3]Soil Erosion Studies — Part II, AGRICULTURAL ENGINEERING, May, 1947, vol. 28, no. 5, pp. 197-201.

The Withdrawal Resistance of Roofing Nails

By Henry Giese
FELLOW A.S.A.E.

NAILS have been used as fasteners for wood for centuries and will probably continue to be so used for many more years. They are easily manufactured, relatively cheap, and on the whole have done a fairly satisfactory job. The demand for them has been so great that on the whole they represent a large tonnage. Nails constitute a negligible factor in the total cost of a roof; hence, even though an improvement resulted in a considerable increase in the unit cost, it would have little influence in the over-all roof cost.

So many nails are used in the application of wood shingles, that the demand per nail is small. The story has been different, however, with other types of roofing, due in part at least to the increased demand upon the nail. In any case it seems necessary to use only nails which are of themselves highly resistant to corrosion or have a protective coating to make them so.

Customary practice in nailing wood shingle roofs calls for upwards of 1000 nails per square. If one were to follow manufacturers' directions explicitly, however, he would use approximately only 450 nails per square of asphalt shingles, 150 on asphalt roll roofing, and 100 on sheet metal. Builders often use fewer than even these figures. From this it is apparent that a nail which would be quite satisfactory for fastening wood shingles might not be so for the other types of roofing.

Nails driven into moist wood lose much of their withdrawal resistance if the wood is subsequently dried. Roofing nails often tend to "creep" or work out of the wood for no apparent reason. Numerous farmers have stated that they simply took for granted the necessity of driving nails back in place periodically on sheet metal roofs.

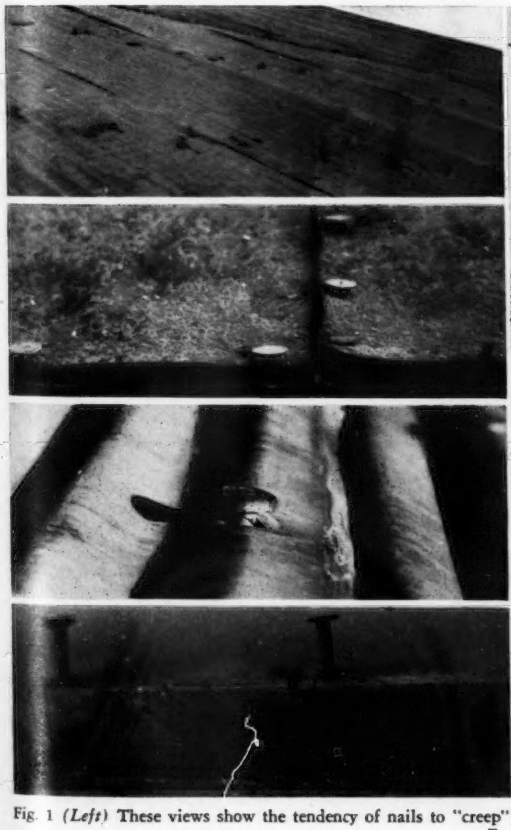
As this report deals exclusively with their withdrawal resistance and tendency to creep, the mechanics of nail holding will first be considered briefly. One might think of a nail as being a bolt which is usually forced to make its own way into the wood and which also is provided with a "nut" which depends for its withdrawal resistance upon the friction between the wood used for the nailing medium and the nail. It is apparent that this friction is not only of questionable value but variable from one nail to another. Three of the variables are wood density, wood moisture content, and the direction of driving relative to the grain. Moisture content varies with time and is influenced by changes in temperature and relative humidity of the atmosphere.

After wood has been dried to approximately 24 per cent moisture, it changes in dimension with changes in moisture.

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Farm Structures Division. Approved for publication as Journal Paper J-938 of the Iowa Agricultural Experiment Station, reporting on Project 562, in cooperation with the Republic Steel Corp.

HENRY GIESE is research professor of agricultural engineering, Iowa Agricultural Experiment Station.

AUTHOR'S ACKNOWLEDGMENT: The author desires to express his appreciation of work done on this project by S. Milton Henderson while research assistant professor, Iowa Agricultural Experiment Station.



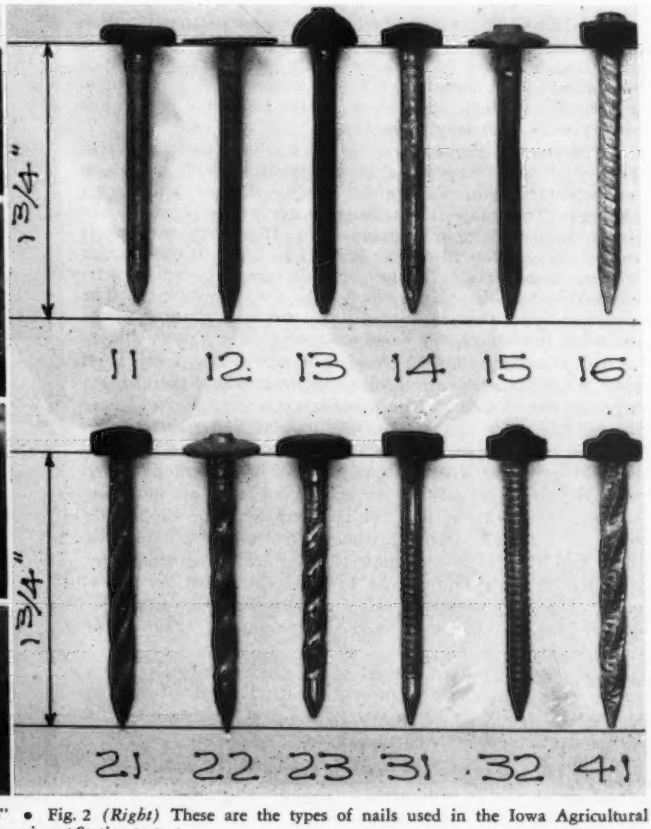


Fig. 1 *(Left)* These views show the tendency of nails to "creep" • Fig. 2 *(Right)* These are the types of nails used in the Iowa Agricultural Experiment Station tests

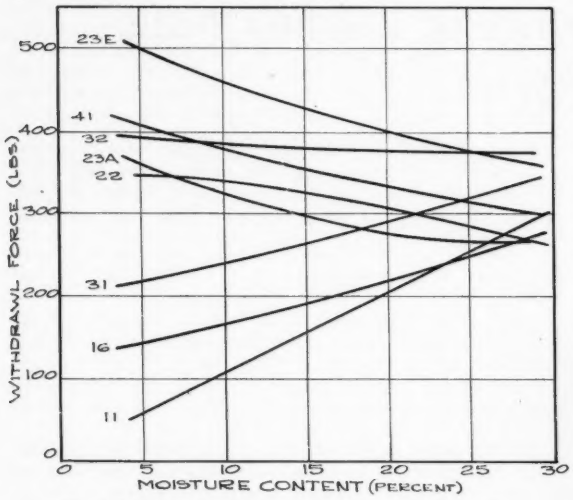


Fig. 3 Withdrawal resistance of nail as related to moisture content of wood

These changes are greatest tangential to the growth rings, less on a radius, and negligible parallel to the grain. If a nail were driven into a bored hole, slightly smaller than the nail, it is probable that the pressure would vary but little due to changes in the moisture content of the wood. Actually, however, the fibers which are displaced as the nail is driven, form a thin layer in which they lay approximately parallel to the axis of the nail. The changes in dimensions of the fibers in this thin section are probably responsible for the loss in withdrawal resistance as the wood dries.

There is little difference in the withdrawal resistance of nails when withdrawn at once, even in a wide range of moisture content. The USDA Forest Products Laboratory states that the difference is in favor of the moist wood. This is probably due to the difference in the effect of the nail upon the displaced fibers. In moist wood the fibers will bend while in dry wood they may be broken.

The phenomenon of creeping has not been explained satisfactorily. Some have thought it associated with expansion and contraction of sheet metal roofing due to temperature changes. This may loosen the nail but probably is not the determining factor, since nails creep frequently in asphalt roofs, and as shown in Fig. 1, even in boxes housed under shelter. Since only a fraction of nails creep, it seems apparent that conditions must be just right for it to happen. The author believes it is associated primarily with changes in the moisture content of the wood into which the nail is driven.

Let us assume that the wood as shown in Fig. 4 will from time to time change in moisture content and that the changes begin at the outside and progress inward. As the wood near the outside dries, the grip on the nail at that point relaxes while it still remains firm near the point of the nail. This means that as the wood shrinks, the nail is not pulled inward with the shrinking wood. As the wood takes up moisture, however, the grip on the nail is increased near the outside while it is relaxed deeper in the wood. As the wood swells then, the nail tends to follow. Movements are small and considerable time is required to produce a marked movement. The nails shown in Fig. 1 as creeping from a box required approximately nine years for creeping a maximum of perhaps ⅜ in.

The results reported in this paper represent only a fraction of the work done and deal primarily with the effect of changes in wood moisture content upon withdrawal resistance of the several nails.

DESCRIPTION OF NAILS

Seven of the 16 commercial roofing nails shown in Fig. 2, representing the four distinct roofing nail types, were used in this study (Table 1). (A complete report of the study appears in a recent bulletin by the author and S. M. Henderson[3].)

For convenience in interpreting results, the first digit in the nail number indicates the type of shank, as follows: 1, plain shank; 2, screw shank; 3, ring shank; 4, combination screw and ring shank. All nails were of galvanized steel.

DUTY OF SHEET METAL ROOFING NAILS

Wind flowing over a roof may cause a lifting effect of 50 lb per sq ft, or a still greater figure if, in an open shed or a building with an opening on the windward side, an increased pressure were built up inside the building. This force might pull the nails out of the baseboards. A preliminary study of

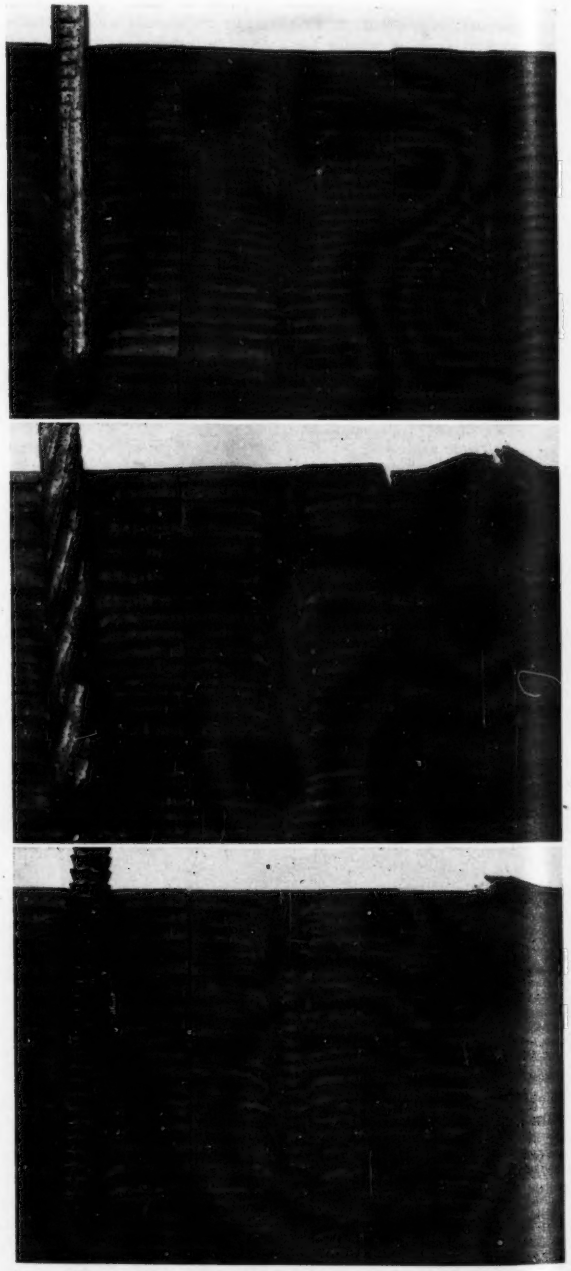


Fig. 4 *(Top)* Displacement of wood fibers by plain shank nail • Fig. 5 *(Center)* Displacement of wood fibers by screw shank nail • Fig. 6 *(Bottom)* Displacement of wood fibers by ring shank nail

TABLE 1. NAIL TESTED

No.	Length	Penetration	Shank	Diameter Wire	Max	Min	P	C-S Area	Screw shank Pitch	Thds	Lead
11	1.78	1.32	Plain	.136			.427	.0146			
16	1.89	1.37	Barb	.140			.440	.0154			
22	1.86	1.38	Screw	.152	.158	.125	.456	.0150	.300	4	1.20
23A	1.80	1.35	Screw	.134	.148	.110	.450	.0134	.240	4	0.96
23C	1.82	1.37	Screw	.135	.163	.102	.475	.0128	.333	4	1.33
23E	1.82	1.37	Screw	.135	.166	.102	.475	.0128	.240	4	0.96
31	1.87	1.34	Ring	.127	.138	.100	.400	.0154			
32	1.89	1.37	Ring	.140	.150	.115	.441	.0177			
41	1.87	1.39	Comb	.137	.172	.120	.513	.0171	.300	5	1.50

All dimensions in inches.

Pitch = 1 ÷ number threads per inch.

Lead = pitch × number threads = depth of penetration for one complete revolution.

P = perimeter.

TABLE 2. AVERAGE WITHDRAWAL FORCE FOR EACH TEST

Test No.	Date, 1945	Moist. Cont., %	Nail 11	16	22	23A	23E	31	32	41
1*	10/11	27.3	265	273	289	275	364	331	384	334
2	10/12	24.7	271	262	286	269	391	325	379	324
3	10/16	19.7	218	206	304	275	386	288	361	308
4	10/29	11.3	101	188	340	364	485	251	403	375
5	11/26	5.8	71	138	342	338	481	220	333	403

*Tests made within half an hour after driving.

the force required to pull nail heads through 28-gage steel showed that the smallest load causing deformation was 185 lb and that causing rupture was 210 lb. On roofs where nails have come out, one cannot detect by observation any bending of the steel.

THE EFFECT OF MOISTURE CONTENT OF WOOD

Ten Douglas fir two-by-four's with a moisture content of about 27 per cent were selected for a series of tests to study the performance of the nails when driven into wet wood which was later permitted to dry. Fifty nails each of Nos. 11, 16, 22, 23-A, 23-E, 31, 32, and 41 were driven through 26-gage sheet steel to a depth of 1⅜ in. The members were dried in a heated room, and 10 nails of each type were extracted at drying stages as indicated.

The results are shown in Table 2 and in Fig. 15. The curves were fitted by eye and are intended to show only the general trend.

Plain Shank Nails. At the left of Fig. 4 the block into which a plain shank nail was driven has been split apart showing the nail in place. The other portion appears in the center. It will be observed that the wood fibers, particularly in the end grain, have been bent downward. At the right is a block from which the nail was withdrawn before the block was split apart. The withdrawing of the nail did not materially change the direction of the fibers as bent downward in driving.

A plain shank nail depends upon friction for its resistance to withdrawal. Changes in the wood which would result in a relaxing of the pressure against the nail would decrease the resistance to withdrawal. The withdrawal resistance was reduced from 265 to 71 lb as the wood dried from 27.3 to 5.8 per cent moisture content, a loss of 73 per cent. Nail No. 16 with a roughened shank was about equal to No. 11 when first driven, but lost only 49 per cent of its withdrawal resistance after the wood had dried, making it nearly twice as good as No. 11 under the latter condition.

Screw Shank Nails. When extracted immediately after driving, most screw shank nails compare directly with plain shank nails in the ratio of their perimeters. The advantage then in deforming nails, lies mainly in the increase in perimeter. All of the screw shank nails, however, increased in resistance as the wood dried.

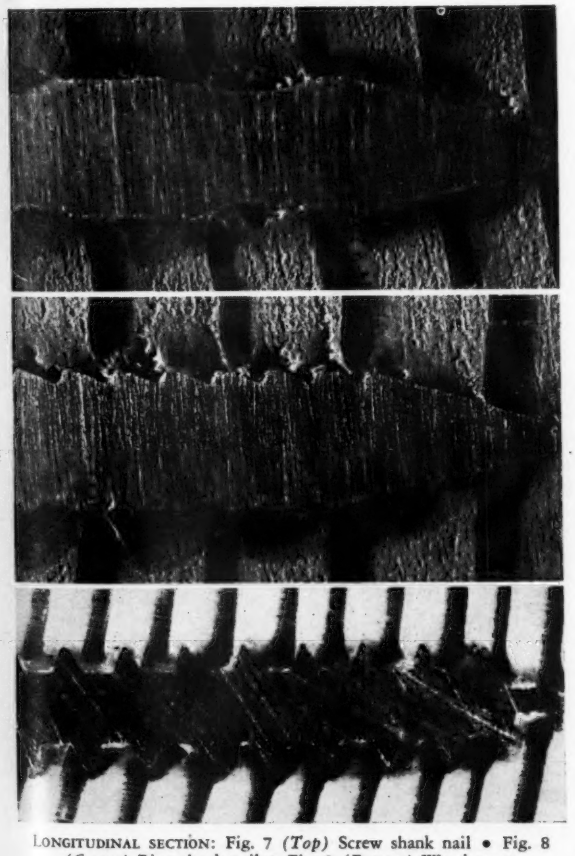
If a screw shank nail is restricted from turning as it is extracted, a portion of the surrounding wood which lies within the threaded section must either be sheared off or compressed to admit passage of the outer portion of the thread. On the other hand, that portion of the surface of the screw shank nail, which is above the root of the thread, exerts little or no resistance to extraction, whereas all of the surface of a plain shank nail is functioning. It would appear then that the gain from shearing of the wood is approximately offset by the loss in effective surface in the screw shank nail. That portion of the thread which lies above the root cannot lose further, while the increase in shearing strength of the wood as it dries more than offsets the loss in surface contact. As shown by Fig. 7, however, the amount of shearing may be less than would be suspected by a casual observation of the nail.

The principal variables in a screw shank nail are its cross section, lead, length of threaded section embedded in the wood, shape of point, and character of head and of surface.

The screw shank nail is designed on the assumption that it forms a thread when driven and that the fibers forming these threads restrict the outward motion of the nail. The verity of this is illustrated in Fig. 5, the two blocks on the left of which, being split apart, show the threads formed. Screw shank nails do not form threads in the sheet metal due to the initial slippage and lack of ability to drive nails straight. The block at the right, which was split after the nail had been extracted, shows also that the threads were destroyed as the nail was withdrawn. The screw shank must turn freely in driving, and fail to turn during extraction if the threads are to be most effective.

Screw shank nails with lead heads do not rotate when withdrawn by a roof corrugation. Nail No. 22, a four-thread nail with a lead of 1.20 in, increased in withdrawal resistance from 289 lb at 27.3 per cent wood moisture content to 342 lb as the wood dried to 5.8 per cent moisture content, an increase of 18 per cent.

Nail No. 41 differs from the other screw shank nails primarily in the roughening of the root of the thread and the consequent formation of what might be termed a combination of screw and ring shank. It is somewhat larger in diameter than the other screw shank nails but loses a part of this advantage because of its large lead of 1.5 in. It failed at a load of 334 lb in the moist wood and 403 lb in the dry wood, an increase of 21 per cent.



LONGITUDINAL SECTION: Fig. 7 *(Top)* Screw shank nail • Fig. 8 *(Center)* Ring shank nail • Fig. 9 *(Bottom)* Wood screw

Nail No. 23 presented problems in analysis due to variations in manufacture. Further observations together with tests on the various samples appear later. In general No. 23 is a four-thread nail (a few five-thread) with a lead varying from 0.96 to 1.33 in. It differs from the other screw shank nails in that the threads were rolled after galvanizing, resulting in a smoother surface.

Nails A, C, and E represent variations obtained in different orders under the same specification. Nails A and B differ in the location of the threaded section, as do C and D. Nails B and D were made by grinding A and C so that the threads extended to the points. The lead varies as shown in Table 1, with A and B being identical and also C and D. C, D, and E differ from A and B in that the threads are rolled to a sharp edge in the latter. In nail E, the threaded section was increased in length from 1 to 1 3/16 in. Nails C and D are superior to A and B because the difference in rolling resulted in a larger maximum diameter. Some loss in effectiveness, however, was noted due to a change in lead from 0.96 to 1.33 in. Nail E is superior to all other forms of nail No. 23 because it has a smaller lead (0.96 in) than C and D, a larger diameter than any of the others, and is threaded to the point.

As the wood dried, nail 23A increased from 275 lb to 338 lb, or 23 per cent in withdrawal resistance, while nail 23E gained from 364 lb to 481 lb, an increase of 32 per cent. If the nail lags from the theoretical rotation when driven, the fibers being bent or severed from their original position cause impaired withdrawal resistance. Comparisons of three variations of nail No. 23 driven are shown in Fig. 11. The zero point of penetration is taken at the extreme end of the nail. It is quite obvious that with all points rotation will begin only when the threads gain a sufficient grip on the wood fibers to overcome the friction presented by the point. The horizontal distance on the chart between the theoretical and actual rotation indicates the amount of slippage. Perfect turning occurs when the curve of actual turning parallels that of theoretical turning.

After being driven approximately 0.2 in beyond the point, there was no apparent slippage of nail B. A similar nail ground to a conical point showed no slippage beyond approximately 0.1 in. Considerable resistance to turning is built up by the unprocessed section of nail A near the point. The effectiveness of the threaded section in overcoming this resistance is further impaired by the fact that the hole made by the unprocessed portion is larger than the root diameter of the threaded section.

How far changes can be carried to improve performance is a matter of conjecture. In the absence of a better criterion, a graphical comparison with wood screws is shown in Fig.12.

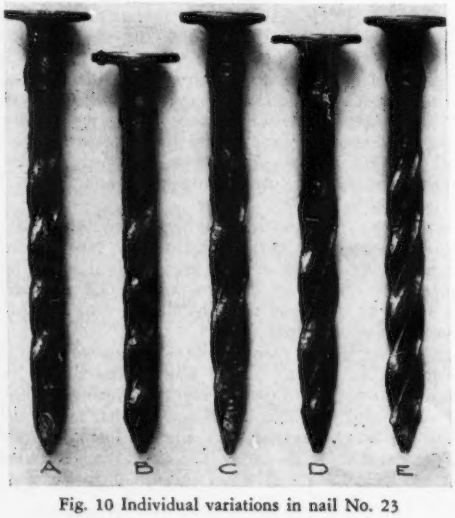


Fig. 10 Individual variations in nail No. 23

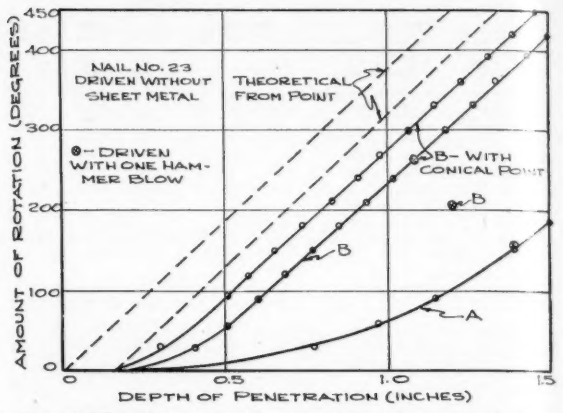


Fig. 11 Effect of type of point upon rotation of screw shank nail No. 23 when driven

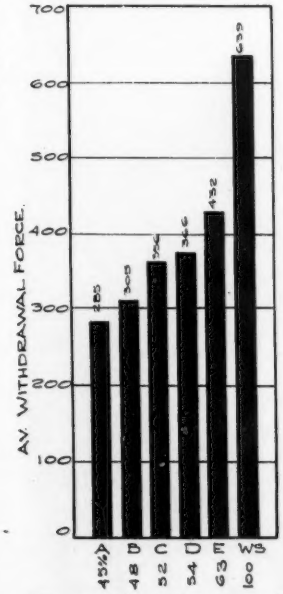
The performance index indicates the relative effectiveness of the various nails with a wood screw of comparable diameter. The length of bar shows the average withdrawal resistance and the figures below the identifying letters show the performance index. A No. 7 wood screw has a maximum diameter of 0.147 in, approximately that of nails 23A and 23B, while a No. 8 wood screw has a diameter of 0.163 in, approximating nails C, D, and E. Comparing each nail with the wood screw of corresponding diameter, the ratio for each nail becomes: A=0.45, B=0.48, C=0.52, D=0.54, and E=0.63.

Nails threaded to the point begin to turn soon after the threads make contact and show no subsequent slippage with a lead as small as 0.96 in. It is probable that this lead could be reduced somewhat without detriment in driving.

Two screw shank nails, type 23B, were sharply serrated* with a chisel on the side of the thread which contacts the wood during withdrawal. These were compared with the original nail as shown in Fig. 13.

The screw shank nail was 50 per cent more effective if restricted from turning when withdrawn. The serrated nail

*Patent applied for.



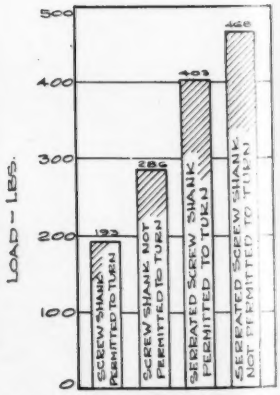


Fig. 12 *(Left)* Performance index of nail No. 23 • Fig. 13 *(Right)* Withdrawal resistance (Plain and serrated screw shank nails, one inch penetration)

was improved only 15 per cent under similar conditions. The serration improved performance 110 per cent for extraction when turning and 65 per cent for restricted extraction.

It seems apparent that serrations on the upper side of the thread would obviate all tendency to creep.

Ring Shank Nails. Ring shank nails may vary in diameter, size and shape of ring, shape of the point, and surface characteristics.

The two ring shank nails tested differ considerably in their characteristics. No. 32 has a maximum diameter of 0.150 in as compared with 0.138 in for nail No. 31, an increase of 9 per cent. Nail No. 31 is processed only for a length of 1 in, leaving in most cases an unprocessed portion just above the point and also a similar unprocessed portion near the outer surface of the wood. In general, the rings were not carefully processed in nail 31, as is apparent in Fig. 14. Difficulty in securing comparable results in later tests was also caused by inferior nails received on a reorder. In Fig. 14 the upper nail of each group represents that received originally and the lower one is typical of the reorder. It is quite apparent that variable results will be obtained when made under such conditions. Nail No. 31 failed at 331 lb in the moist wood and at only 220 lb in the dry wood, a loss of 33 per cent; while nail No. 32 just held its own at 384 lb.

The ring shank nail loses roughly a fourth of its holding ability when driven through sheet metal, as a result of damage to the sharp edges of the rings. If the tip of the nail could be so designed that the hole in the sheet metal would be punched the same diameter or slightly larger than the diameter of the shank, the shank should be relatively undisturbed during the driving process. A few nails were fitted with a heavy ring at the point†. Conical points were machined on several of the regular nails for comparison with the diamond tips, since the special tip had a conical point as well as a shoulder.

Ten nails for each test were driven into Douglas fir perpendicular to the annual rings, and to such a depth that one inch of rings was in contact with the wood. The regular nails were reduced 0.005 in (Fig. 15) in diameter by being driven through the steel sheet; the special tipped nails practically none. The special tipped nail was 21 per cent superior to the regular nail with the conical point, the differences being highly significant statistically. The nails with special rings the same or slightly smaller in diameter than the shank were reduced in shank diameter during driving but the holding ability was not affected. The practical difficulty in driving a nail straight results in some damage to the rings even with nails provided with the special tip with some loss in withdrawal resistance when the nail is first driven through sheet metal.

†Patent applied for.

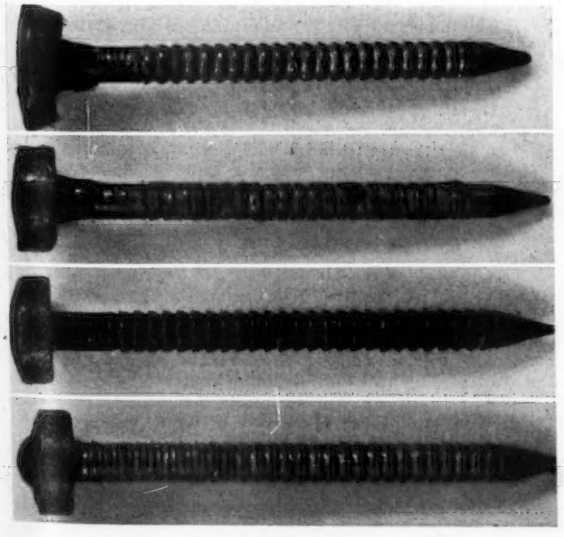


Fig 14 Variations in nails Nos. 31 and 32

Over-all Comparison. An over-all comparison of the nails tested is shown in Fig. 16. Using nail No. 11 as the standard, or 100 per cent, the first bar in each series above the corresponding nail number gives the relative efficiency based on perimeters when nails are withdrawn immediately after driving. The efficiency of a nail is taken as the ratio that its withdrawal resistance bears to that of nail No. 11, divided by the ratio that its perimeter bears to the perimeter of nail No. 11. Nails 16, 22, 23A, and 41 perform almost identically with No. 11. Nail 23E was 24 per cent better, and nails 31 and 32 were 34 per cent and 41 per cent better, respectively. Screw shank nails with a lead greater than 0.96 in show no improvement over plain shank nails when withdrawn at once.

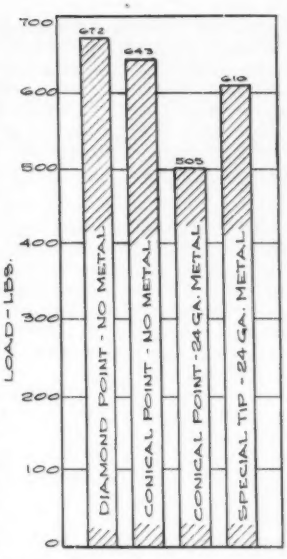


Fig. 15 Average withdrawal resistance of nail No. 32 (one inch penetration)

The second bar shows the relative performance on the basis of the amount of metal in the nail. Heads were removed before weighing to eliminate differences in head weights. Nails 23, 31, and 41 show slight improvement over the comparison based on the perimeter.

The third and fourth columns, however, tell quite a different story. When nails are driven into moist wood and

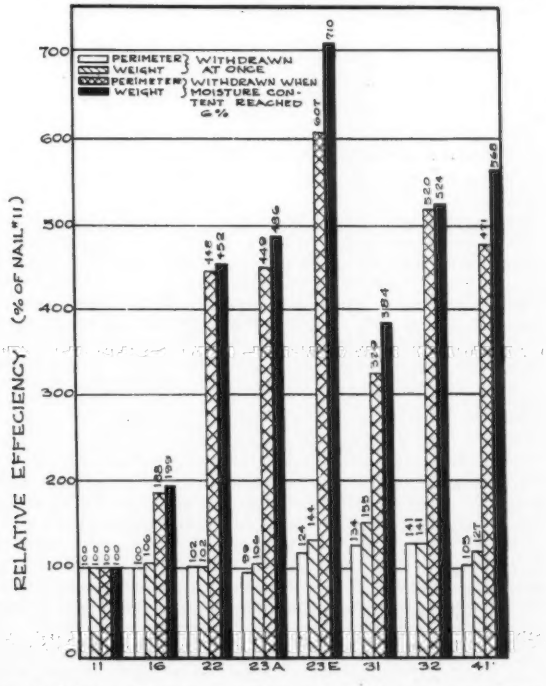


Fig. 16 Relative efficiency of roofing nails based upon comparative perimeter and weight

withdrawn after the wood has dried, all deformed nails show a marked improvement over the plain shank nail. The screw shank nails show greater improvement than the ring shank nail, and screw shank nails with small lead show a greater improvement than those with a longer lead. The superior performance of 23E over 23A is due to smaller root diameter, a larger outside diameter, and the fact that the thread extends to the point with no unprocessed portion intervening.

SUMMARY

The duty of a roofing nail when used to fasten metal sheets has not been stated clearly. It should, however, present a withdrawal resistance comparable to the force required to pull the head through the metal and to maintain this value throughout the life of the roofing. This implies freedom from creeping and from loss in withdrawal resistance in spite of marked changes in the moisture content of the nailing girt.

All nails tested performed satisfactorily when withdrawn shortly after driving. The chief advantage in the processed nails lies in their ability to retain or improve in withdrawal resistance under changes in the moisture content of the nailing girt, and, in some, their resistance to creeping. Variations due to manufacture may cause discrepancies in performance greater than those from one type of nail to another. This fact places a responsibility upon the manufacturer to maintain quality of workmanship.

Plain shank nails lose markedly in effectiveness if driven into moist lumber and withdrawn after it has dried. The withdrawal resistance of nail No. 11 dropped 73 per cent when driven into moist Douglas fir and withdrawn after the wood had dried 21 per cent. Nail No. 16 provided with barbs or irregularities in the surface performed essentially the same when withdrawn at once, but lost only 49 per cent of its withdrawal resistance after the wood dried.

When withdrawn soon after driving, the principal advantage of the screw shank nail lies in the increased perimeter thus obtained. Their comparative performance is, however, improved markedly if driven into moist wood which is subsequently dried.

For maximum effectiveness, screw shank nails must turn freely when driven and refrain from turning when extracted. Nails with a lead as small as 0.96 in showed little slippage in driving, if the thread extended to the point. Screw shank nails with large leads performed essentially like plain shank nails of equivalent perimeter when withdrawn at once. Screw shank nails with small lead and well-formed threads, when driven into moist wood and withdrawn after the wood had dried, attained an effectiveness of more than seven times that of a plain shank nail with equal perimeter. The performance of nail No. 23A was improved from 65 to 110 per cent by serrating the upper edge of the thread. The screw shank nail is relatively unaffected by driving through sheet metal.

The ring shank nail was relatively unaffected by changes in the moisture content of the wood. Driving the ring shank nail through metal damages the rings and impairs its performance by approximately 25 per cent. About three-fourths of this loss can be recovered by the use of a thicker ring at the point which has a diameter approximating that of the other rings. The rings should be well formed and care taken to avoid damage in galvanizing.

The author believes that the ring shank nail or the serrated screw shank nail will not creep.

REFERENCES

Deniston, A. J., Jr. The development and use of roofing nails. AGRICULTURAL ENGINEERING, 14:9-10, 1933.

Gahagan, J. M. and Beglinger, E. New nail treating process increases holding power. Barrel and Box and Packages, 37:21, July, 1932.

Giese, Henry and Henderson, S. Milton. The effectiveness of roofing nails for application of metal building sheets. Res. Bul. —, Ia. Agr. Exp. Sta., 1947.

Langlands, I. The holding power of special nails. (Australia) Council for Scientific and Industrial Research, Pamphlet No. 46, (Division of Forest Products—Technical Paper No. 11), Melbourne, Australia. 1933.

Markwardt, L. J. and Gahagan, J. M. Report on tests to determine the effect of nail points on resistance to withdrawal. Timberman, 31:107-108, 110, 1930. Also Barrel and Box and Packages, September, 1930.

. . . How surface condition of nails affects their holding power in wood. Barrel and Box and Packages, 37:7-8, September, 1932.

. . . The mechanism of nail holding. Barrel and Box and Packages, August, 1931.

. . . Nail holding tests made. The Timberman, 30:142-143, August, 1929.

Maze, J. S. New developments in roofing nails. AGRICULTURAL ENGINEERING, 18:405-6, 1937.

Wood Handbook, USDA Forest Products Laboratory, Revised 1940.

Soil Transportability by Surface Flow

(Continued from page 444)

have greatest effect on soils of low transportability and least effect on soils of high transportability.

If a soil is of such low transportability that the particles are transported by dragging or rolling across the surface of a field, very much less energy may be required to move them down the steeper grades. These differences in energy requirements will tend to cause more soil transportation on steep slopes than on gentle slopes, even though transporting capacities of the erosive agents are equal on the different slopes. If there is considerable spread in the degree of slope on different hillsides, a slope correction must be used in the transportation equation to account for these effects of slope on the relative ease of dragging and rolling soil materials downhill. Equation [1] will then read

$$T'_1 = (T'_2, T'_3, \text{slope}) \quad \ldots\ldots [3]$$

The slope factor in this equation relates only to differences in work requirements for transporting soil materials down inclined planes that have different degrees of slope. For example, if the factors of T'_2 and T'_3 were about equal on two different plots, one having a 5 and the other a 15 per cent slope, there may be twice as much soil transported on the 15 per cent slope because of differences in work requirements for moving materials down 5 and 15 per cent slopes.

A second factor that has direct effects on soil transportation is that of surface irregularities. Small surface depressions and ridges may have an outstanding effect on transportation of soil particles that are of such low transportability that they are transported only by rolling and dragging them across the surface of a field. These irregularities will have much less effect on soils of high transportability.

When this surface factor is introduced into equation [3] it then reads

$$T'_1 = f(T'_2, T'_3, \text{slope}, \text{surface}) \quad \ldots\ldots [4]$$

It should be a fairly easy matter to set up experiments where these factors are varied one at a time and the effects of each on the transportation of soil is determined. In the first stages of the experimental work the factors of slope and surface should be standardized for evaluating the factors of T'_2 and T'_3. Not until after T'_2 and T'_3 have been evaluated will slope and surface be varied and effects of these variations studied.

Certainly all of the factors shown in equations [1] to [4] will have significance in our studies of soil transportation by surface flow that occurs outside of deep rills, gullies, and channels. After considerable depth of flow has been reached, the factor of D_3 in equation [2], and the factors of "slope" and "surface" in equation [4] may decrease in their importance. We do not know at what depths these decreases occur, but certainly they take place at much greater depths than those we find covering more than 95 per cent of most sloping fields during rainstorms. Because of this, and for other reasons, the authors believe that new types of transportation experiments, designed to study the factors outlined in this discussion will prove to be of great value when working with problems of soil transportation by surface flow.

Pressure-Membrane Apparatus — Construction and Use

By L. A. Richards

ULTRAFILTRATION apparatus has been used for many years in chemical and bacteriological work and consists of a chamber into which the liquid to be filtered can be poured and subjected to considerable pressure. A porous filter pad or membrane, supported on a screen or perforated base, makes up the lower wall or bottom of the chamber. To prevent the passage of small particles, the pores in the filter membrane must be small. This causes low membrane permeability, makes necessary the application of pressure, and gives rise to the term "ultrafiltration".

Apparatus very similar in general arrangement and construction to that used for ultrafiltration has been adapted and used for soil moisture work[4,5,8*]. Usually a wet but not saturated soil sample is mounted on the membrane in the filter chamber, and the gas pressure within the chamber is used to create a condition of the membrane such that the membrane extracts moisture from the soil. Equipment for this kind of use in soils work has been called pressure-membrane apparatus. Although it was designed originally for extracting solutions for analysis from saline soils[3], it has been found useful for studying the moisture retention characteristics of soils and other materials[6], and for the calibration of soil moisture instruments[2].

The amount of moisture retained in soil which has come to equilibrium with the membrane in the pressure-membrane apparatus depends on the gas pressure in the chamber. The higher the pressure the more moisture is removed. The apparatus is finding numerous applications in agricultural soils laboratories because it makes possible the direct determination of the "*equivalent* negative pressure"† or tension in the soil moisture as related to the moisture content of the soil.

The curve relating negative pressure, or soil moisture tension, to moisture content has been referred to as the "soil moisture characteristic curve", or, more briefly, the "moisture characteristic"[1], and because of its fundamental significance will no doubt find increasing use in agricultural engineering and soil mechanics work relating to the soil moisture system.

Since the introduction of pressure-membrane apparatus for use in making measurements on soil moisture, the design has been altered and improved considerably, and it is the primary purpose of this paper to give design details that have been worked out at the U. S. Regional Salinity Laboratory and have proved to be satisfactory.

Fig. 1 is a drawing of the parts for the apparatus and Table 1 lists the various parts and specifies the materials required. Fig. 2 gives diagrams of the pressure source and connection manifold and Fig. 3 shows the assembled apparatus.

The bottom plate of the chamber which is shown as part 1 in Fig. 1, consists of a steel casting that is machined to fit the tripod legs, part 11. The upper surface of the bottom plate is recessed to take the screen base, part 6, which serves as the support for the membrane, and on top of which the soil is placed for extraction. The vertical wall for the extraction chamber is formed by the cylinder, part 5. This cylinder may be rolled from brass strip and joined by a silver-solder butt joint. A gasket is required to cushion and make the seal between the cylinder and the cellulose membrane. This gasket, (see part 5, Table 1) should be cemented to the cylinder.

The top plate, shown as part 2, forms the upper wall of the soil chamber. The castings for the top and bottom plates are identical, but are machined differently. Since most castings are somewhat porous, the gas seal at the top plate is made by a thin sheet copper liner, part 3. The top liner fitting, part 8, is soldered into the inner hole in the top liner with soft solder. The top liner can be attached in place in the top plate with bonding cement or soft wax. The liner fitting, part 8, is then secured in place by a jam nut, part 20.

TABLE 1. Parts and Stock

Part no.	No. req.	Description
1	1	Bottom plate, steel casting, tensile strength 70,000 psi
2	1	Top plate, steel casting, tensile strength 70,000 psi
3	1	Top liner, 12-in diameter circle, copper sheet, 20–30 gage
4	1	Diaphragm, 12-in diameter x 1/16 in, C-3773, black rubber, U. S. Rubber Company
5	1	Cylinder, ¼x½x38-in, brass. Roll from strip and silver solder
	1	Cylinder gasket, 12-in diameter x 1/16 in. Redman Red, U. S. Rubber Company
6	1	Screen base assembly
	1	Screen base, 12-in diameter x 1/16 in, brass sheet
	1	Screen, 12-in diameter, 100-mesh brass
	1	Doubler, ⅜-in diameter x ⅛ in, brass
	1	Tube, 0.096-in diameter x 1¾-in copper tube
7	1	Diaphragm fitting, ⅞-in diameter x 2⅝-in brass rod
8	1	Top liner fitting, ⅞-in diameter x 2⅝-in brass rod,
	1	5/16 x 5/16 x 1/32-in brass sheet
9	1	Handle, ¾ x ¼ x 9-in, brass bar
10	2	Handle spacer, ½-in diameter x 1⅛-in brass rod
11	3	Leg, ½-in diameter x 4⅜-in brass rod
12	2	Hose fitting, ¼ NPT to ¼ hose, brass, standard oxygen fitting with union nut attachment, 9/16-in NF thread
13	2	Capscrews, ¼-in NF x 1½-in steel, hex head
14	8	Bolts w/ nuts and washers, ⅜-in NF x 3¾-in steel, hex head
15	2	Welding hose for ¼-in fittings, 24-in lengths required, 1,200 psi bursting pressure
16	1	Setscrew, ¼-in NF x ¼ or ⅜-in, steel, socket head
17A	1	Reducing valve, 3,000 psi inlet gage, 300 psi outlet gage, Model 511, Hoke, Inc., 122 Fifth Ave., New York City
17F	1	Connector, 3/16-in copper tubing, ¼-in rubber hose (same as 18F and 19K)
18A	1	Reducing valve, 300 psi outlet gage, Model 505, Hoke, Inc., New York City
18C	1	Pressure switch, 30–440 psi, 10–60 psi differential, Class 9100, API, Square D Co., Detroit, Mich.
18E	1	Check valve, ½-in No. 27, brass, oil-resistant, plastic valve seat, Crane
19A-D	4	Needle valves, ⅛ or ¼-in NPT, Models 329 or 309, Hoke, Inc.
19E	1	Laboratory test gage, 0–300 psi, 1 psi graduations, Ashcroft Hancock Co., Bridgeport, Conn.
19F	1	Manifold, ¼-in brass pipe, fittings as required
20	2	Jam nut, 9/16-in NF x 5/16-in hex, brass
21	4	Hose clamp, to fit OD of part 15

When moisture is being extracted from fine-textured soils, especially if the samples are thin, dehydration is accompanied by shrinkage which tends to pull the soil sample away from the membrane. To avoid this, a diaphragm, part 4, has been provided. This diaphragm is sealed into the top plate against the top liner by use of an annular ring of automobile bonding cement or weather strip cement applied around the periphery of the diaphragm. The diaphragm fitting, part 7, should be coated with bonding cement and inserted in the diaphragm and the top plate, before the diaphragm is cemented to the top liner. The diaphragm fitting is then pulled gently into place by a jam nut, part 20, and is anchored with a setscrew, part 16. No gasket is required on the upper face of the cylinder because the diaphragm completes the closure at this joint. A handle, part 9, is screwed to the lugs on the upper part of

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

L. A. RICHARDS is senior soil physicist, Regional Salinity Laboratory, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Riverside, Calif., in cooperation with the eleven western states and the territory of Hawaii.

*Superscript numbers refer to appended references.

†The expression "*equivalent* negative pressure" is used because it is not known over what range of soil moisture contents, less than saturation, water is actually present in a liquid phase and outside the range of the adhesive force of the soil particles. Neglecting effects arising from the compressibility of water, the pressure in the chamber when the outflow from the soil has ceased is equal to the negative pressure or tension to which the extracted soil solution must be subjected to give it the same free energy as the solution has when it is subjected to surface force action in the soil.

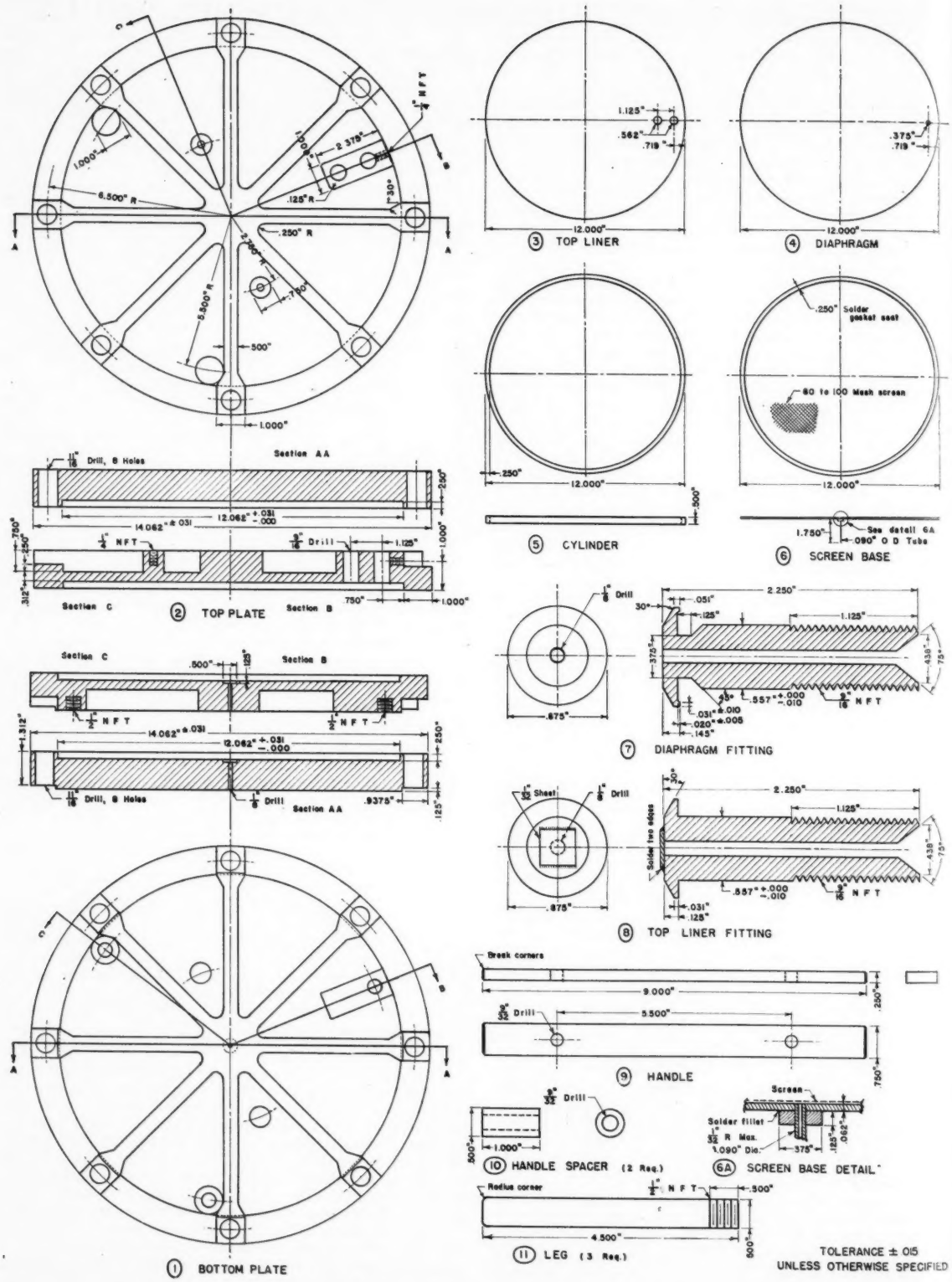


Fig. 1 Parts for pressure-membrane apparatus

the top plate with ¼-in cap screws which pass through the handle and the spacers, part 10.

The screen base, part 6, is perhaps the most difficult piece of the apparatus to construct. The hole in the screen base plate (See detail 6-A in Fig. 1) should be centrally drilled at the time when the plate is mounted in the lathe for cutting the outer edge. This hole should be a snug fit for the 0.096-in outside diameter capillary copper tubing which serves as the outflow for solution from the extraction chamber. A thickness doubler or collar made of ½-in brass serves to reinforce the connection to the brass plate and is soldered to the brass plate with soft solder. If this solder and the heat are sparingly applied, this connection with attendant parts can be removed and renewed at a later time, if necessary, without disturbing the screen.

The function of the screen on the screen base is to supply uniform, adequate support for the membrane and still allow liquid passing through the membrane to move freely toward the outflow tube. Since it is desirable, especially in certain extraction processes, to collect all of the extracted liquid, it is necessary to make a tight connection between the membrane and the screen base at the outer edge. This requires soldering around the periphery of the screen base. It is a bit difficult to put on this ring of solder smoothly and keep the screen taut without supplying sufficient heat to warp and buckle the plate permanently. One procedure is to stretch the screen at a number of opposite points and tack with solder. Then use a circular plywood template to guide the soldering copper while making a smooth and continuous soldered surface that serves as the gasket seat.

The pressure fittings, parts 7 and 8, are shaped so that connection can be made directly to standard oxygen fittings, part 12, and high-pressure, flexible rubber hose, part 15, such as is used on gas welding equipment.

If a number of pressure-membrane cells are to be placed in service, a pressure manifold should be arranged along the laboratory bench as indicated diagrammatically in Fig. 2, part 19. While ⅛-in galvanized pipe has been used for this manifold at the Laboratory, it is believed that ¼-in brass pipe with silver-soldered joints would be more suitable. Brass needle valves, parts 19A-D, are needed for individual shutoffs at points H, where the high-pressure rubber hose connects to the manifold.

Compressed air and water-washed nitrogen have been used at the Salinity Laboratory for extraction work. If soil solutions are being extracted for chemical analysis, nitrogen should be used to avoid possible chemical disturbances which might come from compressed oxygen and CO_2 in the air. Nitrogen is commercially available, and we have found pressure-reducing valves such as Hoke Nos. 511 and 505, (parts 17A and 18A, respectively) to be satisfactory for pressure control.

When the apparatus is used for moisture retention studies on soils, compressed air is believed to be entirely satisfactory, and in the long run the convenience of having a compressor that will supply the required pressure is more practical than using tanks of compressed gas. A small refrigeration compressor driven by a ½-hp motor has been used at the Laboratory. A 4-ft length of 4-in galvanized iron pipe has been used as the compressed air storage tank. The pressure control limit switch, part 18C, has been set to operate between 280–320 psi. A check valve is used between the compressor and the tank, part 18E‡.

The pressure required to operate the diaphragm for holding soil samples against the membrane has been obtained from a differential mercury manometer such as is shown in Fig. 2, part 19. Connection is made at K to the pressure source. The needle valves C and D in the low and high-pressure manifolds are used for connecting to the pressure-membrane cell. The manifolds can be extended as needed to operate additional

‡ The Cornelius air compressor which has recently been available from wartime aircraft surplus and salvage is ideally suited for pressure-membrane use. It is a three-stage unit with a maximum operating pressure of 1500 psi and is direct coupled to a 24-volt d-c motor. The motor is series wound and can be operated by 25 v, 25 amp a-c through a step-down transformer. The built-in pressure-control switch can be set to operate between 300 and 500 psi which is convenient for use with a pressure-regulating valve. Some of these units have been sold by General Surplus Stores, 1439 Grand Ave., Kansas City, Mo.

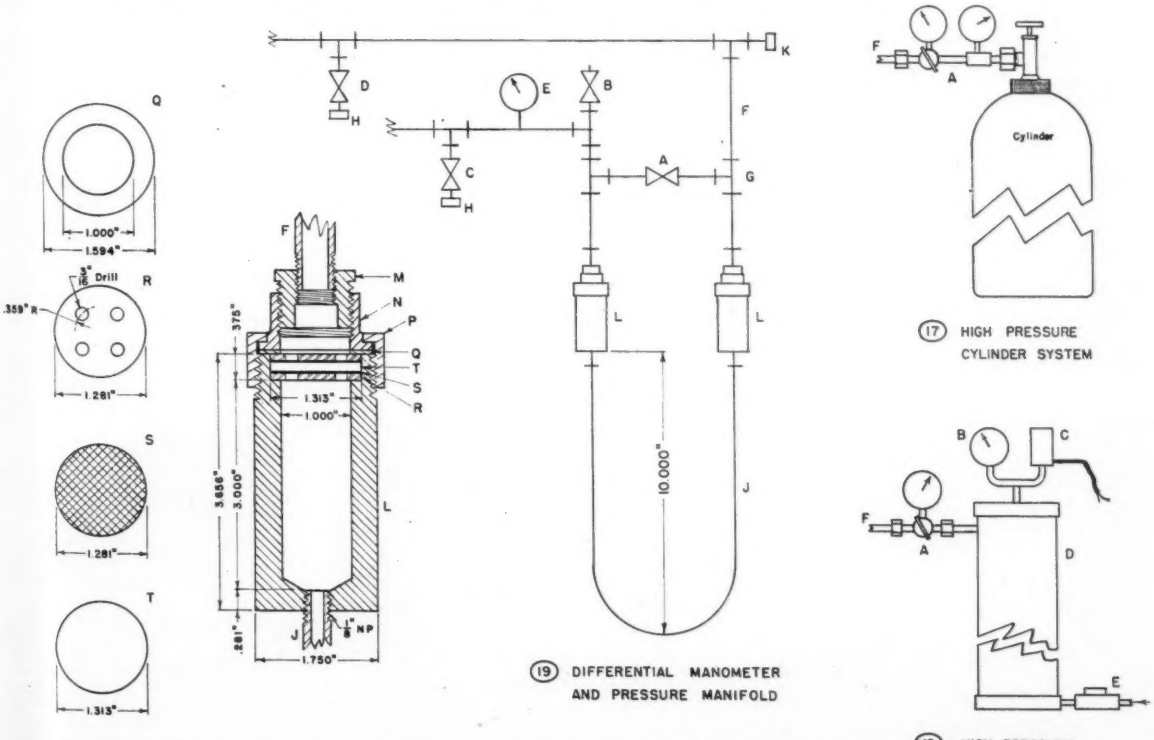


Fig. 2 Diagram showing pressure source, differential manometer, and manifolds (See text for explanation)

pressure-membrane units. The iron U tube, J, can be bent up from ⅛-in black iron pipe or steel tubing. A porous plug, L, on each side of the manometer should be arranged so that accidental large pressure differences across the manometer will not remove the mercury from the manometer system. Parts from ¾-in pipe unions, N and P, can be used to facilitate construction and also for subsequent inspection and repair. The porous washer, T, may be leather or felt, and can be supported between screens, S, and perforated steel plates, R. Glass cloth can also be used and is not subject to bacterial decomposition. A soft rubber gasket, Q, is needed to complete the seal. Sufficient mercury should be placed in the manometer so that approximately 4 psi gas pressure is required to bubble air past the mercury.

To put a pressure-membrane unit in operation, the cock, A, is opened and air is admitted to both manifolds at the pressure at which the extraction is to be made. After a few hours, the rate of outflow of water from the apparatus falls off appreciably, and the soil moisture samples attain sufficient rigidity that the diaphragm pressure can be applied without excessive deformation or compaction of the samples. At this time, the cock 19A is closed. Cock 19B is then opened until air is heard to bubble past the mercury in the U tube, at which time it is again closed. The pressure of the air from the source is then adjusted to give the desired extraction pressure on the gage 19E.

If other pressure-membrane units are already in operation from the manifolds, the procedure for connecting on a new unit is as follows: The cock at the manifold is opened to admit compressed gas only to the soil chamber. When extraction has sufficiently progressed, the cock supplying air to the diaphragm chamber may then be opened, and the soil-chamber line should be vented slightly at cock B to allow the diaphragm to move down in contact with the soil, and to take care of any excess pressure that may be brought about in the soil chamber during this downward motion, since the pressure in the upper manifold is maintained at about 4 psi greater than in the lower manifold. The small plate shown soldered to the end of top liner fitting, part 8 in Fig. 1, prevents damage to the diaphragm during the foregoing operation.

After a newly assembled unit has been put together, it should be thoroughly tested for safety. This can be done by filling the unit with water before applying the test pressure. A pressure of 300 lb for a safety test has been considered adequate if the cell is to be used at pressures no higher than 215 psi plus 4 psi for the diaphragm differential.

For certain types of experiments, a diaphragm is not used, and it is unnecessary to make connection to the top liner fitting, part 8. For soil moisture instrument calibration work[2], the cylinder shown as part 5 in Fig. 1 can be replaced by a cylinder as tall as may be required. Cylinders 2 in and 4 in high have been found useful. Such cylinders can be cut from standard 12-in O.D. x ¼-in-wall steel tubing. However, if steel is to be used for the cylinder it must be adequately protected from rust, because cellophane membranes will be injured within a few hours if they are allowed to come in contact with iron rust.

It has been found that for studying the moisture-retaining characteristics of soils, cellulose sausage casing has been very satisfactory**. Visking membrane has been successfully used at the Laboratory in extraction cells which have been operated at pressures up to 2,600 psi or about 177 atmospheres. When it is desired to study chemically the solutions extracted from soils, considerable care should be taken with the washing and preparation of the membranes[3] and membranes as thin as possible should be used. Plain, transparent cellophane of thickness gage 600, 450, and 300†† have all been successfully used. Occasional failures may be expected with the thinner membranes, apparently due to the action of sharp sand grains in the soil.

The apparatus may be quickly prepared for use. The screen base is inserted in the bottom plate and covered with a sheet of cellophane which has been previously moistened. The cylinder with a gasket on the lower surface is then pressed into place and the membrane is trimmed by running a knife blade around the outside of the cylinder. The soil is placed on the membrane, moistened for the required length of time[6], and the top plate is then placed and secured with bolts. At the end of a run, care must be taken in opening the chamber to make sure that the break occurs between the diaphragm and the cylinder, otherwise the membrane may be raised, with a consequent disturbance of the samples. If necessary to prevent this type of disturbance, a sheet metal turn button can be attached to the bottom plate so as to latch into a groove in the cylinder. The need for such a turn button will depend on the tackiness of the particular kind of rubber used for the diaphragm.

If it is desired to measure the moisture retained at any given pressure for a number of samples[6], the samples can be placed in retaining rings on the membrane. Rings of about 2-in diameter and ⅜-in high can be cut from tire inner tubes. Individual soil samples should weigh at least 25 g or excessive care will be required to obtain a representative sample for the test. Replicate determinations will agree within 0.1 per cent of moisture if the subsampling process does not introduce differences in mechanical composition between replicates. The time required to attain equilibrium increases rapidly with the height of soil sample at pressures above one atmosphere. It will generally be desirable to keep the depth of sample on the membrane ⅜ in or less for routine determinations with cellophane membranes if large numbers of soils are involved.

Because of the large difference in permeability and the consequent rate of approach to equilibrium, ceramic membranes are preferable to cellulose for the one atmosphere pressure range[6,7]. Satisfactory results at pressures up to ½ atmosphere have been obtained from preliminary trials using a disk of calf leather instead of cellophane in the pressure-membrane apparatus. It has been found necessary occasionally to treat this leather to protect it from microbial decomposition. An occasional soaking in copper sulfate or mercuric chloride appears to give adequate protection. A sample height of as much as one inch can be used for permeable soils on leather or ceramic membranes and still attain equilibrium in an overnight extraction period. The number of samples that can be handled on a given membrane area can thus be greatly increased for low tension determinations.

The small outlet tube in the screen base, as shown in part 6, Fig. 1, is connected by a tight-fitting rubber sleeve to a similar piece of copper tubing which extends laterally and connects to the tip of a buret. The buret can be supported in a buret clamp which is screwed to one of the legs of the chamber. Gas diffusing through the membrane passes continuously in small bubbles through this small outlet tube, and keeps the extracted liquid trans- *(Continued on page 460)*

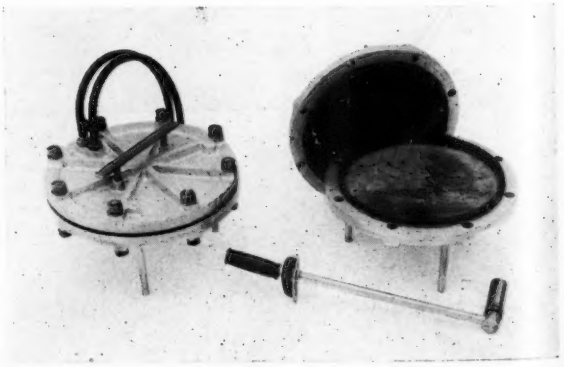


Fig. 3 Pressure-membrane units, open and closed. A calibrated torque wrench is also shown

**Visking cellulose sausage casing 5½ in x 20 ft, high stretch. The Visking Corp., 6733 W. 65th St., Chicago 38, Ill. Seamless cellulose tubing, 20 ft x 4½ in. Sylvania Industrial Corp., 122 E. 42nd St., New York

††Plain transparent cellophane. No. 300, 0.00088-in thickness; No. 450, 0.0012-in; No. 600, 0.0017-in. E. I. du Pont De Nemours and Co., Inc., Wilmington, Del.

Research Procedures for Cooperative Projects with Limited Personnel

By F. A. Brooks
FELLOW A.S.A.E.

COOPERATIVE research has been practiced in the agricultural experiment stations for the past sixty years, and the research reports of the past twenty years frequently carry multiple authorship showing a coordination of efforts of two to five men per project. The extensive accomplishments were, however, rarely noticed outside of agriculture. In contrast, World War II research involving hundreds of men per project gave such spectacular results that now the general public seems to take miracles of science for granted, and Congress is told what wonders can be obtained if only it provides generous support for research. So I believe the following question is pertinent. How do we proceed to get the expected results if money is available for research?

There have been several postwar papers on large-scale cooperative research. Those by Chancellor Arthur Compton,[1]* Washington University; Vannevar Bush[2], director, OSRD (civilian war research), and Walter Murphy[3] editor, "Industrial and Engineering Chemistry", bring out ideas pertinent to research procedure in agricultural engineering. Dr. Compton made a clear statement of the special value of cooperative research before the American Philosophical Society, November 16, 1945. On this subject he said:

> "In no field is the growing importance of such cooperation more evident than in that of scientific research. . . . . The development of the methods for producing plutonium is typical. At the peak there were engaged on this one problem roughly five thousand laboratory workers in seventy odd locations studying different aspects of this single problem. . . . . No one person could be skilled in every field or understand even the meaning of the answers to the many problems. But somehow, the group mind integrates such knowledge into the useful form that results in a process that successfully produces plutonium.
>
> "There remains, happily, a valuable place for the individual research man who masters and advances his own limited field of study. His specialty, however, is of little value except as a part of a broader field. More and more we find that even in a limited field a team of men with different specialties working together does the most effective work. New thoughts develop in their discussions. More refined techniques are available. A team which thus supplies a combination of originality and special skills is the pattern toward which research is moving.
>
> "Cooperation is the very lifeblood of a society based on science and technology. Such a society is necessarily made up of specialists, not only men of science and engineers, but also skilled laborers, salesmen, administrators, educators, and legislators. Working alone, such specialists are useless. When their work is co-ordinated they form a society of enormous strength."

Vannevar Bush discusses in some detail the national organization of research, and Walter Murphy brings out the remarkable accomplishments of cooperative research in the intense development of a small segment of science. In all these, the basic explanations of the spectacular results are about as follows: complete interchange of technical knowledge and the availability of eminent talent, teamwork of a high order between the investigators, and a willingness to try out ideas on a pilot-plant scale before their validity is proven.

The essential difference, therefore, between our customary cooperative research and war research is the almost unlimited manpower, money, and priorities willingly focussed on war research. Without the urge to preserve our freedom, large gathering of "eminent talent" is of course impossible, even if there were ample funds, so there is little prospect of postwar research approaching the speed of war research.

A distinction must be made, however, between pure and applied research. Only applied research or development is discussed in this paper. Pure research, namely, research purely for the sake of new knowledge without intention as to application, was largely forsaken during the war and will flourish in peacetime in proportion to the support given and to the degree of academic freedom allowed the scientists.

Modern Inadequacy of Individual Research in Agricultural Engineering. Bearing in mind that our technical problems concern the transition from an old practice (depending largely on crude observations of nature) to a new one (depending more on scientific modification of nature), it is readily seen that we must be thorough enough in our research to lay a sound foundation. A short-sighted solution might soon itself become obsolete, while a comprehensive solution can be developed into a somewhat permanent future practice. For example, consider the recurring fires in airplane dusting with sulfur. The operators are cautious now in the specification of the sulfur dust; some use special plywood bins; some "keep everything clean, always wash the plane down"; all the pilots keep a sharp lookout to the rear, alert to shut off the dust feed and fly away from an incipient fire. Yet last summer in California four airplanes dusting with sulfur caught fire on the same day when there was a dry north wind. Now we see a new direction in which to seek the answer. Dry air maintains the electrostatic potentials and also increases the rate of flame propagation. So this project should have had the attention of several men: entomologist, biochemist, climatologist, electrophysicist, combustion engineer, and the airplane pilot.

As a more complex example where a restriction in scope may prevent the solution of a problem, consider the question: Why is it that fifteen or twenty experiment stations have been working for years on the problem of hay curing without reaching a satisfactory understanding? The reports at the 3rd Barn Hay Curing Conference sponsored by the A.S.A.E. at Chicago last December showed extensive progress, but on a rather individualistic basis. Maybe a good solution has been found by a single individual or experiment station group, but the present situation is a strong indication that conclusive findings are more likely to be reached by the combined efforts of several individuals.

Besides needing cooperation for thoroughness, we need cooperative projects for quick results. In this period of rapid change, the duration of investigation of a method of operation must be reasonably short or else the original objectives must be revised repeatedly. For instance, of what use will be research in machines for dry dusting if the trend to liquid spraying makes dry dusting obsolete? Long-term research using exclusively either liquid or dry materials would be warranted only if the basic problem of whether dry dusting or liquid spraying is best for agriculture is settled. The latter question itself is too large for a single individual unless he has time to become expert in entomology, engineering, climatology, animal husbandry, and economics, all as applied to this specific problem.

It is true that some engineers strive to become agriculturists, and that many agriculturists do their own engineering. Most of us, however, prefer to depend on the expert in the branch of science with which we are concerned. There is some tendency for agriculturists to think that engineers should be adept in all fields of applied physics. Their logic runs this way: Physics is the realm of direct cause and effect, an exact (easy) science not needing statistical methods essential in the (difficult) life sciences. So our agricultural partners often expect us to give specific answers and to make effective applica-

An address presented before the 40th Annual Meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Committee on Research.

F. A. BROOKS is agricultural engineer, California Agricultural Experiment Station.

*Superscript numbers refer to appended references.

tions from all branches of industrial practice, not sensing the vastness of industrial technology nor the concurrent gaps in knowledge. Even some physicists think engineering is easily stepped into, if they have not been confronted with demands for quick, practical results in spite of limitations in help and costs.

In the general attitudes expressed above there is, however, widespread faith in being *trained* in the existing body of scientific knowledge. There is no indication that we expect any change in the laws of nature. We are trying mainly to fill the huge gaps in knowledge which still exist in all branches of applied science. It is for work within these unconsolidated regions of knowledge that *experience* is so vital. Dean L. M. K. Boelter[12] stated this at Purdue University last summer substantially as follows: "The engineer senses the magnitudes of variables which can neither be formulated nor evaluated. Extrapolation from system to system with the details unknown is indeed hazardous for acceptable results, but it is the exercise of this procedure which accounts for the stature of the professional engineer."

In a sense single-handed research is itself cooperative in that no one can work effectively without using the vast knowledge already found by others. And the individual cooperates with all scientists when he publishes valid findings. In this paper, however, cooperation means concurrent collaboration toward a jointly recognized objective. The principal difficulties in cooperative research are still in the adjustments each individual has to make when he tackles a new problem and works with new companions.

In regard to the natural limitations of the individual, Dr. Hettinger[4] has published illuminating observations on the restrictions in mental vision, mental worlds, and scope of knowledge to be expected of human beings. It is encouraging to note that all these limitations can be minimized by cooperative procedure. For instance, Oliver Wendell Holmes noticed that an idea often grows better when transplanted to another mind. And recently in an address to research-minded students Dr. Wagensteen[5] presented the following simplified outline of how the individual research worker functions:

> "The most fundamental requisite of a research project is an idea. A person with an idea who also possesses a capacity for critical analysis is partially equipped to solve a problem. If in addition he is master of a method or technique which is suitable for the investigation, the situation is even more promising. Frequently, however, these two abilities in ideas and techniques are not found in the same individual. It is often necessary, therefore, to combine the talents of two or more investigators. Also, since there are facets in many problems fully understood only by certain persons, the final solution of a problem might be quickened by decades if an over-all picture could be put together by a fusion of knowledge and methods. Basic to the success of scientific method is, of course, the universal validity of findings which establishes a finality of proof and agreement which puts aside all speculative rationalization."

Considering the statement: "validity of findings which establishes agreement," it appears that the usual argument over technical papers indicates that research procedure needs to include *demonstration of validity*. Fortunately for agriculture it is to be noted that finality of proof does not require exact investigation of every minute part, because, as shown by Schroedinger,[6] detailed knowledge is not necessary if the statistical behavior is known within the permissible range of error.

Research procedure very properly is concerned with how to foster the mental growth of an idea and how best to promote agreeable human relationships without destroying individual responsibilities. These two topics are ably discussed by W. H. Easton[7] and by W. J. King[8] and will not be outlined here.

Passing by the vital problems of human nature, the technique of fitting individual efforts together is still of interest, even assuming that each cooperating research worker has ideas, a capacity for critical analysis, and some proficiency in techniques. In the ideal arrangement each project leader would be responsible for only one phase of the project, and all phases could be added together without conflict. Such specialization might be by different fields of knowledge as in the usual complex research in agricultural engineering, or by parallel lines of attack as in the development of airplanes, or by both as in war research. Subdivision by different fields of knowledge is particularly advantageous in groups having a wide range of personal abilities. The pertinent question, therefore, in subdivision of the subject matter is: What are the various phases of a complex research problem which have semi-independent status? Some suggestions for this can be seen in the large-scale research on war problems, where unlimited teams contributed several parts. At least we can learn what range of investigations one man should have covered if there had been the usual limitations in personnel that we are faced with now in agriculture. This raises another question: What are the desirable technical qualifications of the various cooperators as to training and experience? Both of these questions show the need for some broad scheme for classifying a project to avoid scatter-brained procedure and to reveal the personal difficulties in the necessary retraining and transfer of experience.

Naturally no amount of financial support is effective unless it provides for the real needs of the research workers. The work of the research personnel is continually changing, so an essential requirement for the project is considerable flexibility in support. Great care is needed to insure that limitations in support do not channel the lines of study contrary to the free choices of the project leaders. Secondary objectives in the support are to provide for sufficient range of investigation to assure the reliability of the findings, and to promote personal meetings as a desirable method of cooperating. The typical conference where twenty or more research workers hastily give individual progress reports on a complex problem is not cooperative in Dr. Compton's sense of "the group mind integrates knowledge into useful form." This integration can, however, be approached if the project support provides for out-of-state travel expenses of individuals who would participate actively as extra workers needed for occasional group effort on distributed phases of the problem. Such research-worker cooperation is never achieved by administrative "coordinating" committees, but only the latter has ready approval for travel expenses.

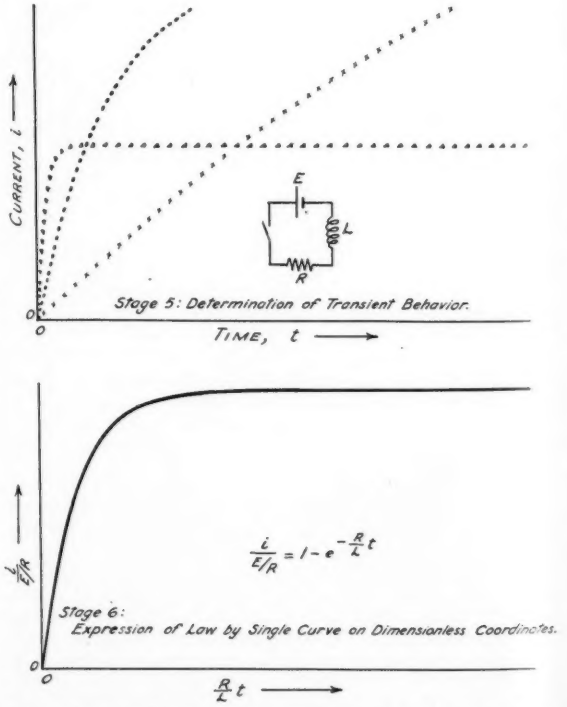


Fig. 1 *Top:* This graph shows a variety of transient response curves each describing correctly the behavior of a given circuit, but not useful for understanding circuits with different constants. *Bottom:* The generalized response of the same circuit useful for all cases

In the foregoing general discussion of cooperative research, a few major topics appear to be worth more detailed presentation. These will be treated under these headings: validity of findings, transferability of training, transfer of experience, and multiple approach.

TECHNIQUES FOR REACHING VALID FINDINGS

To clarify the discussion of collaboration in research, it is helpful to consider the procedures employed to assure the correctness of conclusions. The over-all question and proof is: does it work? Maybe it does under certain conditions, but what about other conditions? For example, a California Agricultural Experiment Station project on animal environment as related to pork production involves natural climate too hot for swine, but favorable for low production costs. If the results of shade and spray systems are measured by the well-being of the animal, the findings are direct, inclusive, and positive to the degree indicated by statistical review. But not knowing *why* a modification is successful, it cannot be applied directly to any other locality. Rather than blindly try it everywhere in the United States, isn't it worth while instead to try for a general understanding, or at least to become able to specify the limitations in application?

Some years ago Dr. Bancroft[9] attacked the usual research procedure for following the Baconian inductive method of generalizing from the particular. The main objection is against the lack of a guiding idea in the making of experiments. But Francis Bacon himself stresses the advantage of having a light and only insists that axioms be educed from facts[10]. Bancroft cites 50 misleading experiments without showing they disprove Bacon's philosophy. All were narrow in range and most were failures to notice an unexpected variable. He then closes with a good quotation—"The evidential value of any fact is an unknown quantity until the fact has been explained." This seems to suit Bacon's procedure exactly. So Dr. Bancroft's complaint against the usual procedure in applied research—"First get your facts"—should be against failing to follow through on Bacon's fundamental ideas on generalizing from empirical findings. This follow-through is greatly facilitated in cooperative research.

A little review of procedure habits in establishing validity reveals that the keystone of the technique is to run a balance. The surveyor doesn't usually stop three-quarters of the way around a tract and specify the fourth side by remainder; he closes his survey and notes the error. A machine designer runs a force and torque balance. A biochemist runs a carbon balance. A banker insists on a money balance. In all these examples of a total transformation we know our degree of observational error if we measure all the ins and outs and by balancing determine the discrepancy.

The next degree of the balancing technique is to measure all the rates into and out of a continuous-flow process. This involves one independent variable. The heat-transfer engineer knows his degree of error in the steady state if he measures separately the rates of heat transfer by conduction, convection, radiation, and by thermodynamic transformation, and notes the discrepancy from total heat production. The balance on transient conditions such as cyclic temperatures and batch processing involves two independent variables. And the full comprehension may be reached in systems (having no discontinuities) when a wide range of observations can be expressed as a single curve on coordinates of dimensionless criteria (Fig. 1). For biochemists the ultimate is the synthetic production of a biological substance. They already know the amino acids which are the foundation of the all-important proteins.

In the above three classes of phenomena—quantities, steady rates, and transients — the mathematical equations specify the balances, namely, the algebraic equation and the respective differential equations. These are the equations of conservation and continuity, and the form by which the physical laws of nature are expressed. The differential equation is the most general, being freed first of initial conditions. Then by including space variables the differential equation is freed of boundary conditions. Thus when the conditions are specified the solutions of the defining differential equations give all the answers. This is the reason scientists feel unsatisfied until they can generalize their findings by expressing them analytically.

In general the empirical development of a valid theory of any system proceeds about as shown in Table 1. The greatest difficulty is often in the earlier stages, but the degree of understanding is indicated approximately by the stage which represents current research. A simple example of the last step expressing a law of nature is shown in Fig. 1.

TABLE 1. EMPIRICAL DEVELOPMENT OF A VALID THEORY

1 Bare observations,
2 Interpretation under local conditions,
3 Investigations of the effects of change in conditions (physical balances),
4 Analytical expressions including rates of action,
5 Determination of transient behavior, and, sometimes,
6 Expression of law by single curve on dimensionless coordinates.

An important part in reaching valid findings is the noticing of the unexpected. There is always a possibility of overlooking some influence which is constant in one set of experiments and variable in other conditions of application. Dimensional analysis is no help in such cases. A review of all the force fields, however, might be illuminating, and if the cooperative project includes an expert in each group of fields, the probability of missing an essential factor by default is minimized. Of course the main factors in noticing the unexpected are alertness and experience which depend in this respect on the degree of personal interest in the problem. Fortunately personal interest usually develops as the inherent difficulties of a problem come to be recognized, but there are important "ambient" conditions to be satisfied if, for instance, new insight is needed on baffling questions. Some of these are discussed by Easton, previously cited.

Research can be planned in a comprehensive manner favorable for noticing the unexpected. The common engineering example is the measuring of all the modes of heat transfer and the total rate. This occasionally reveals a significant change in one mode too small to be evident without a complete balance. Another aid for noticing the unexpected is instrumentation for precise measurements. For instance, narrow-range instruments should be used, and, when humidity is important, dewpoint indicators instead of hair hygrometers. Simple, final aids for noticing the unexpected are to regularize the timing of readings and to systematize comparative tabulations in such a way that discrepancies become very obvious.

Instrumentation for Complex Observations Designed to Reveal Irregularities. One of the great advantages of recorders over indicators is that observations are automatically recorded at regular time intervals. Such systemization greatly extends the possibilities of statistical interpretations and is essential in studies of cyclic changes. For instance, last fall to take some temperatures in a 2500-ton pile of sugar beets, 24 thermocouples were installed with a photoelectric potentiometer indicator. In the beginning, readings were made irregularly varying from ¾ to 4 hr apart, and furnished the answers asked for. The results were so interesting, however, that later probably 20 times as much effort was spent interpolating the readings as would have been necessary to set up and maintain a recording potentiometer. We would gladly have thrown away 95 per cent of the recorder paper, using only the two-hourly readings, to get the regularity needed for understanding the diurnal behavior of the stock pile.

On a major project relating livestock productivity to environment, the surest procedure is to measure environment in terms of its most elemental components, and to record animal response in the detail expected in laboratory research. This prospective data is so voluminous that special effort must be made to take observations in such manner as to facilitate the reduction of the data, and in addition yield statistical indices of reliability.

In general for any variable it is essential to determine (a) a mean magnitude (over some given time interval, repeated), (b) the standard deviation or range of the variable (during each time interval, repeated), and (c) the variance of the mean (in repeated observations).

Often the deviation (b) is not needed, but some oscillations such as those due to turbulence might be more significant than the mean from which they deviate. The replication variance (c) is essential for some indication of reproducibility, and becomes more valid as the number of replications increases.

To be able to try numerous correlations between environmental factors and animal conditions involving voluminous data it is almost necessary to use a punched-card system. This system of handling data does not require prethought as to what reductions are to be made. Its basic limitation is that it can operate only on recorded, quantitative observations. This requires a code for any qualitative remarks usually entered as "comments". Since each card should carry the record of all observations at a given hour, it is worth while to arrange for simultaneous, automatic recordings, and to make all eye readings in regular consecutive order as close to the specified time as possible.

The usual recording potentiometers do not present the observations in convenient form. The mass of dots on a 16-point recorder all have to be read by eye against a ruled scale and then operated on to get means and deviations. So a few years ago we asked for a recorder that would print in 16 columns three digits each. The suggestion got routed to one company's patent attorney and we were sent many reasons why this was not an invention, but received no column-printing potentiometer. Now a combination of electric demand meters and integrating potentiometer has been devised to give us three printed tapes for hourly totals of ultraviolet, visible, and long-wave radiations. Furthermore, it seems that we can ourselves make the modifications necessary in a 16-point electronic potentiometer to get 16 printed columns of thermocouple temperatures typed on a 10-in paper roll in a 15-min cycle. Calibration and scale adjustments are of particular importance in automatic recording systems, so it is desirable to get variable-range instruments with adjustable zero, and to set up an ample calibration laboratory.

PROJECT SUBDIVISION COMPATIBLE WITH TRANSFERABILITY OF TRAINING

Cooperative research is by nature a group effort and each individual worker tends to get some special field of action to work in, somewhat distinct from the work of the other cooperators. It is, therefore, of interest to consider what may constitute distinctive divisions of an engineering problem. Consideration of the characteristic balance employed reveals numerous divisions of engineering science, and, of course, extensive overlapping. As an arbitrary list, Table 2 can be used for this discussion. It is evident that such a list affords a method of subdividing a research project. More important, however, is its significance for considering personal *training* vs. *experience*. It seems that any subdivision on the basis of fields of science primarily concerns technological training rather than experience, though these are not separable. To get a clearer concept of subdivision by fields of training an extreme case may be of interest, where graduate instruction in engineering science is subdivided into specialized fields. Table 4, column 1, gives this year's list of the engineering college of the University of California at Berkeley[11].

TABLE 2. PARTIAL OUTLINE OF "FORCE FIELDS" OF ENGINEERING SCIENCE

"Force field"	Balances	Common specializations
(a) Mensuration	Dimensional	Instrumentation; control
(b) Gravitation and force	Force, momentum, work	Mechanics of solids, fluids, elasticity
(c) Molecular matter	Transformation	Metallurgy; plasticity
(d) Distributed matter	Mass	Combustion; mass transfer; diffusion
(e) Temperature and energy	Heat, energy	Heat transfer; thermodynamics; processing
(f) Wave radiation	Wave energy	Electronics; illumination; acoustics
(g) Electric and magnetic	Electrodynamic	Electrodynamics; power transfer
(h) Human and economic	Recognition, money	Operations; safety; business

All these contribute to the environment of agriculture

These 16 specialized fields of engineering science can all be assembled in five or six groups of Table 2, which latter, therefore, can be considered to represent somewhat distinctive types of science training (and experience) needed by anyone who is to work proficiently in those categories of applied science. There are, of course, large overlappings and the choice of branches is highly subjective. Everybody would make a different list. But the few outlined in Table 2 will serve here to focus attention on some of the differences of competence in applied sciences we expect of men in the various fields of engineering. This serves as a rough guide to judge for ourselves or others the difficulties to be expected when, because of limitation in research personnel, we must work outside our fields of experience or training.

Transferability of Training Among Branches of Engineering Science. Considering now the physical nature of the various balances (suggested in Table 2), we can see that there are explicit differences between the various "force fields," but also that there are extensive analogies across the divisions. The existence of analogies plainly indicates such similarities in their mathematical treatments that a man trained in one field can often transfer his capabilities to allied fields without serious loss. For instance, spring-mass vibration systems are readily expressed by electrodynamic equations; hydrodynamic stream functions, electrostatic fields, surface tension, and stress concentration are all expressed by the same mathematical equation. Problems in heat transfer are solved by setting up analogous electric circuits; and the loud-speaker horn is designed by steam-nozzle formulas. Obviously a man expert in this type of solutions could work effectively with them in any branch of science where they were applicable. Therefore, the customary divisions in science are not due to unique patterns of thought, but primarily to the necessity of restricting one man's training to a small enough portion of scientific knowledge to give him some specialized competence. The important conclusion from this brief analysis for the setting up of cooperative projects with limited personnel, is to show that a person's technical training is largely transferable among allied fields of engineering science.

PROJECT SUBDIVISION TO FAVOR TRANSFER OF EXPERIENCE

Since apportionment of a project by specialized branches of science would emphasize technical training rather than experience, it may be helpful to consider the natural individual aptitudes and the range of science over which one person tends to be proficient. Again, not expecting to find any mode of dividing scientific knowledge that will avoid gross overlapping in characteristic patterns of thought, there are certain fields of knowledge that seem to have semi-independent status. If there is some natural inclination, such as for electronics that leads to such divisions, these might be very useful if we do not expect the various categories to be mutually exclusive.

Boelter[12] has suggested four "system" groups, which he agrees should be expanded to include living organisms. These five are listed in Table 3. The point worth considering regarding Table 3 is whether these "systems" do not represent rather well some major talents of human beings? Each "system" group involves several branches of engineering science, yet this list parallels the broad, customary divisions of professional engineering. It is synonymous with civil, mechanical, elec-

TABLE 3. SYSTEM GROUPS NATURAL TO CHARACTERISTIC APTITUDES

System groups	Professional category
Structures	Civil engineering
Machines	Mechanical engineering
Circuits	Electrical engineering
Processes	Chemical engineering
Living organisms	Agriculture, anthropology

The behaviour patterns of these ideal systems are established by data from the physical and life sciences.

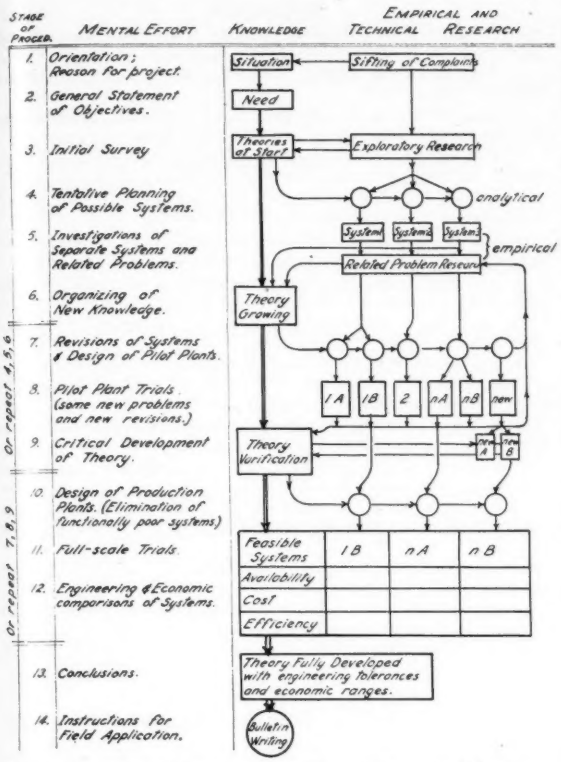


Fig. 2 A hypothetical diagram of the "Flow of Research Effort" in a cooperative investigation using multiple lines of approach

trical, and chemical engineering, and agriculture. Does such a list, then, probably represent a natural classification based (unconsciously) on the inborn aptitudes of human beings?

For instance, circuits are second nature to the ham radio operator; and in every town there are some boys with a perpetual itch to get their fingers into machines. The other headings — structures, processes, and organisms – are not so easy to point up as natural aptitudes visible in children, unless one stretches the meanings to cave digging, cooking, and care of animals.

Of course, it is foolish to think of any division as exclusive, but it is pretty clear that research involving circuits will suffer if a structures expert is asked to transfer his talents and experience to it. In general, it seems that these system groups concern experience more than training. And when we look for more extreme examples depending on experience, the specialized "know how" seen in the unit-operations seem appropriate.

Again, there is no generally accepted classification of unit operations, but the chemical engineers have reviewed their technological progress[13] under eighteen titles, most of which belong in the process classification of system groups. These titles, slightly modified in view of the discussion by Boelter, and to suit the natural bias of the agricultural engineer, are listed in the second column of Table 4. This list of unit-operations is most useful when considering recognized, specialized categories of industrial technology in which experience is directly applicable to a large range of engineering problems. The techniques characteristic of the various unit operations are not bound to certain branches of engineering science, but are found to be somewhat comparable throughout industry when segregated by "unit operations." These then represent important regions of transferability of experience comparable to the list in column 1 of Table 4 of specialized branches of science within which there is easy transferability of training.

It is to be noted in Table 4 that several of these unit-operation systems are the same as some major fields in engineering science. This overlapping indicates the intermingling of training and experience.

TABLE 4. SPECIALIZED BRANCHES OF ENGINEERING SCIENCES AND DISTINCTIVE UNIT-OPERATIONS

Branches of engineering science having specialized training	Unit operations having distinctive techniques and experience	Agricultural examples of unit operations
Dynamics and elasticity	Forming	Seedbed shaping, plastic molding
Electrodynamics	Shearing	Mowing, chopping
Electronics	Shaping	Machine-shop turning, boring, grinding
Structural mechanics	Size reduction	Crushing, pulverizing, particle grinding
Soil mechanics	Separation	Centrifuging, gravity shaking, sedimentation
Fluid mechanics	Filtration	Porous mat, dynamic impingement, electrostatic
Mechanics of aerosols and fumigants	Spreading	Fertilizer spreading, seeding
Heat transfer	Adsorption	Seed treating
Mass transfer	Absorption	Humidification
Radiation and illumination	Dehydration	Drying, evaporation, mass transfer
Thermodynamics	Heat transfer	Environment control, frost protection
Combustion	Fluid flow	Irrigation, ventilation
Mineral sciences	Mixing	Feed balancing
Metallurgy	Gaging	Testing, instrumentation, batch proportioning
Plasticity	Orientation	In processing, color sorting
Processing	Transportation	Materials handling
	Storing	Food preservation
	Advertising	Product labeling
	Cost accounting	
	Accident prevention	

OUTLINE OF MULTIPLE-APPROACH PROCEDURE

Distinct from the need for cooperative research to cover wide fields of applied science is the need for simultaneous investigation of alternative solutions of a problem in a limited field such as represented by the four systems of harvesting sugar beets: Topped in the ground, dug before topping, lifted by the tops, or lifted by a spiked wheel. To study all these approaches conclusively, the ideal organization would have one project leader and staff for each major system and each semidetachable problem, so that the whole investigation can go forward in all its aspects simultaneously. This is ordinarily an extravagant procedure, and when, as usual, research personnel and funds are limited, problems must wait their turn, but the research can still follow parallel lines of investigation. A moderately wide approach can often reveal the practical range of the variables sufficiently to indicate the direction of the optimums and the rates-of-change of variable effects. Thus is it possible that a well-planned, multiple-approach procedure may so broaden the qualitative solution of the main problem that trial application might be warranted without determining the optimum of each component.

The A-bomb project affords the great example of virtually unlimited, multiple-approach research. The urgency was great, cooperation was excellent, and the project achieved its aim. It may be useful, therefore, to study its extravagant procedure as an extreme case which might reveal some relations not evident in agricultural projects entailing cooperative research. Examining the Smyth[14] report to understand the flow of research in the A-bomb project, it is seen that the procedure can be considered in eight or ten stages. Possibly the most significant step was the decision to investigate the four possible systems of development and related problems simultaneously and intensively. This called for a

separate leaderships and assistants in the main lines, and a rapidly expanding research staff as semi-independent problems were encountered. The distribution of segregated problems to large staffs of specialists permitted some grouping of problems, particularly in metallurgy. A great number of studies went forward simultaneously, some faster than others, but most to a logical conclusion. If there had been limitation of personnel, these dependent problems would have been interruptions in the main development and the problems would have been tackled in successive order.

The new knowledge contributed to the growth of nuclear theory and in the revision of plans, time-consuming operations were soon recognized, and three of the systems were found to be workable. (The fourth system, that the Germans chose, may yet prove to be the most perfect, but it was not the most practical.) Thus a fundamental rule for quick results demonstrated in this research procedure is to develop simultaneous multiple lines of attack. The corollary is that each line of attack should be dropped only by logical process of elimination, after multiple attainment of the desired objective, not by midpoint comparisons.

Interpreting the A-bomb research procedure in more modest scale for, say, a major cooperative research project, with limited personnel, the procedure outlined in Fig. 2 seems appropriate. This outline for cooperative research along multiple lines takes advantage of the tendency of scientists toward single-line thinking, in that a person tends to promote the idea he initiates. It also recognizes that for rapid progress each project leader must be free to develop his research in the manner he believes is most hopeful. It seems, therefore, that the least number of independent research workers desirable for a large project is the number of major lines of approach plus the number of major problems common to two or more lines of approach. More severe limitation in man power does not prevent the development of a research project along multiple lines of approach, but requires more transfering of capabilities, and prolongs the time required to reach valid conclusions. The danger in such transfer is the natural bias for the first approach. There are some problems, however, which do not suffer much from first bias. For instance, in the synthesizing of vitamins and enzymes, the multiple choices are of such common nature that the successive trials are not likely to suffer from personal bias.

A more significant difference between simultaneous and successive studies of the multiple lines of approach is the discrepancy in completion dates. The first mode of solution may become obsolete (unless additional time is taken to further improve it) by the time the last system is worked out. In terms of the degree of refinement (in developing each line of attack), it is natural that the most difficult will go slowest. This means that in simultaneously multiple studies the simplest will inevitably look most promising, while in successive studies the difficult line will tend to absorb all the available time.

For a complicated research project, therefore, the most promising procedure is to organize enough man power for simultaneous investigations of the various lines of approach, and provide for completion of more than the simplest system.

SUMMARY

Basic to all research are careful observation and systematic procedure which insure the validity of findings. The essential advantages of cooperation in applied research are that it broadens the mental view of the problem and takes advantage of the range of specialized training and experience of the cooperators. The difficulties of transferring and applying scientific training can be judged by the closeness of the branches of engineering science involved in going from old problems to new. And the transferability of experience might be judged by the "system groups" involved. Both training and experience are, of course, inseparable, and are the intangible tools with which a research man produces. The multiple-approach technique is primarily designed for speed of accomplishment but also can be used to make certain that good alternative solutions are not overlooked.

REFERENCES

1 Compton, Arthur H. Atomic Energy as a Human Asset. Nature (London), vol. 157(3980):146-51, Feb. 9, 1946.

2 Bush, Vannevar. Beyond the Atomic Bomb; Suppl. to Fortune, vol. 32(3), Sept., 1945.

3 Murphy, Walter J. The Fruits of Cooperation. Industrial and Engineering Chemistry, vol. 39(3):235, March, 1947.

4 Hettinger, J. Psychological Handicaps in the Search for Truth. Nature (London), vol. 148(3755):473-74, October 18, 1941.

5 Wagensteen, Owen H. Research and the Graduate Student. American Scientist, vol. 35(1):107-113, January, 1947.

6 Schroedinger, Erwin. The Statistical Law in Nature. Nature (London), vol. 153(3893):704-5, June 10, 1944.

7 Easton, W. H. Creative Thinking and How to Develop It. Mechanical Engineering, vol. 68(8):697-704, August, 1946.

8 King, W. J. The Unwritten Laws of Engineering. Mechanical Engineering, vol. 66(5):323-26, May, 1944.

9 Bancroft, Wilder D. Methods of Research: I - Back to Aristotle; II - The Misleading Experiment; III - How to Think. Rice Institute Pamphlet, Vol. 15(4):167-352, October, 1928.

10 Larrabee, Harold A. Reliable Knowledge (see p. 125). Houghton Mifflin Co., 1945.

11 University of California Graduate Announcement in Engineering. Mimeograph manuscript, May 8, 1947, p. 3.

12 Boelter, L. M. K. A Discussion of Engineering Teaching, Agricultural Engineering Teaching Symposium, Purdue University, August 31, 1946.

13 Industrial and Engineering Chemistry, vol. 39 (1) : 71 A, 3-42, January, 1947.

14 Smyth, Henry D. (consultant, Manhattan District, U. S. Engineers) Atomic Energy for Military Purposes: The Official Report on the Development of the Atomic Bomb under the Auspices of the U. S. Government, 1940 to 1945. Princeton University Press, 1945.

Pressure-Membrane Apparatus

(Continued from page 454)

ported to the buret. The buret can be read periodically and the approach to equilibrium can thus be followed. If the pressure in the extraction chamber is maintained constant, no measurable amount of change in the buret reading can be observed over a period of many hours or days after equilibrium is once attained.

It has been found desirable for new operators to use a cylinder head wrench with a torque calibration scale for tightening the chamber bolts, because it is possible to spoil the gaskets by needless excessive tightening. A torque of 10 ft-lb is satisfactory for the leather membrane for use at pressures less than 15 psi. A torque of 25 ft-lb is usually adequate for pressures up to 225 psi.

AUTHOR'S ACKNOWLEDGMENT: The author wishes to acknowledge the skilled assistance of John Fletcher in the construction of several sets of apparatus in the instrument shop of the laboratory; and the preparation of drawings by Clyde Glasson.

REFERENCES

1 Childs, E. C. The use of soil moisture characteristics in soil studies. Soil Sci., 50:239-252. 1940.

2 Haise, H. R. and Kelley, Omer J. The relation of electrical and heat conductivity to moisture tension in plaster blocks. Soil Sci., 61:411-422. 1946.

3 Reitemeier, R. F. and Richards, L. A. Reliability of the pressure-membrane method for extraction of soil solution. Soil Sci., 57:119-135, illus. 1944.

4 Richards, L. A. A pressure-membrane extraction apparatus for soil solution. Soil Sci., 51:377-386, illus. 1941.

5 Richards, L. A. Pressure-membrane extraction apparatus. U. S. Patent No. 2,353,760. Dedicated to the free use of the People in the Territory of the United States. July 18, 1944.

6 Richards, L. A. and Weaver, L. R. Moisture retention by some irrigated soils as related to soil moisture tension. Jour. Agr. Res. 69:215-235, illus. 1944.

7 Richards, L. A. and Fireman, M. Pressure plate apparatus for measuring moisture sorption and transmission by soils. Soil Sci., 56:395-404. 1943.

8 Woodruff, C. M. Soil moisture and plant growth in relation to pF. Soil Sci. Soc. Amer. Proc., 5:36-41. 1940.

Calculations for Land Gradation

By Grant E. Chugg

AT PRESENT there are several methods in use for calculating or obtaining grade lines for land leveling. These, however, have limitations, such as slope approximations, etc., or they are limited to rectangular fields. In actual practice many of the fields to be leveled are irregular in shape.

Using the method of least squares makes it possible to compute irregular as well as regular fields with balanced cut and fill near a minimum.

The following procedure is suggested in obtaining field data to minimize office calculation time: By stadia or other means obtain approximate length and width of field. From this information and the topography determine the necessary equal distances for both width and length of field for a grid system of layout. Then with the use of rod and level secure the required elevations of the field to be leveled.

A suggested form of taking level notes for grid points is shown in Fig. 1. These same notes will be used throughout this paper for purposes of illustration and as examples.

In order to get a clearer picture of the field, and more space for computations, transfer the calculated ground elevations to cross section or similar paper, as in Fig. 2.

To obtain any elevation at a particular point on a plane systematically, the following equation is used:

$$E = E_o + S_x X + S_y Y$$

In this equation E is any elevation, E_o is elevation at origin, S_x and S_y are slopes of X and Y axes, respectively, and X and Y are any given distances on the X and Y axes.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

GRANT E. CHUGG is agricultural engineer, Region 6, Soil Conservation Service, U. S. Department of Agriculture.

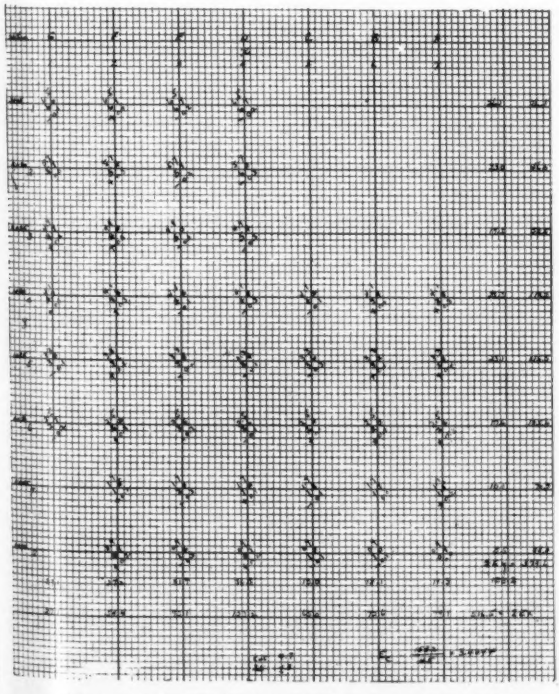


Fig. 2 Work sheet for determining amount of cut or fill

In order to obtain an approximate solution of the above equation for an unknown number of elevations, the method of least squares will be used. Multiply each of an unknown number of equations by the coefficient of X in the equation and add the corresponding sides of the resulting equations, obtaining the "normal equation" corresponding to X:

$$\Sigma(EX)_1 = \Sigma(X^2)_1 S_x + \Sigma(XY)_1 S_y.$$

(NOTE: E_o being a single constant, is omitted.)

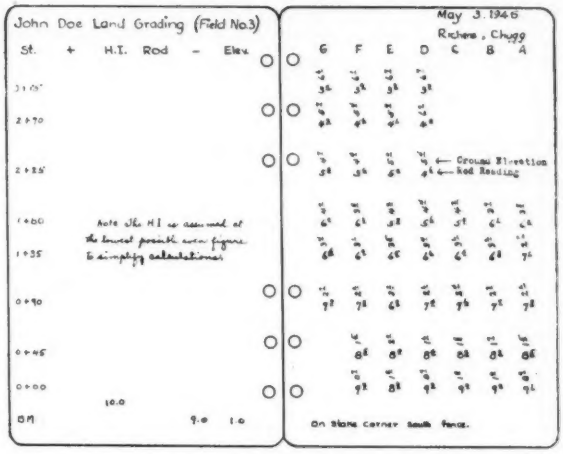

John Doe Land Grading (Field No.3)
May 3. 1946
Richens, Chugg
St. + H.I. Rod - Elev.
G F E D C B A
Ground Elevation
Rod Reading
Note: The H.I. is assumed at the lowest possible even figure to simplify calculations.
10.0
9.0 1.0
On stone corner South fence.

Fig. 1 Sample pages from an engineer's notebook

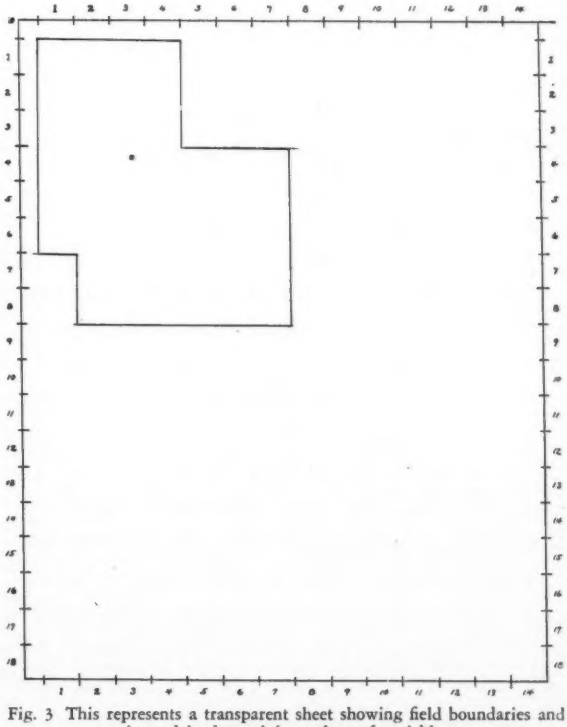


Fig. 3 This represents a transparent sheet showing field boundaries and is used in determining values of variables

Repeat the foregoing step using Y instead of X, obtaining the equation:

$$\Sigma(EY)_1 = \Sigma(XY)_1 S_x + \Sigma(Y^2)_1 S_y.$$

The foregoing two normal equations are values adjusted to deviations from the centroid and the calculated values are obtained through the use of the following supplemental equations:

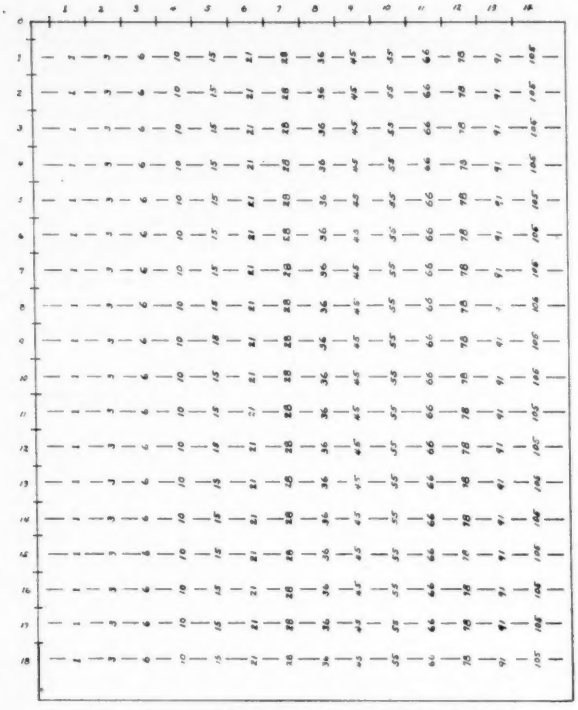


Fig. 4 Sheet used in finding the value of the X_c factor

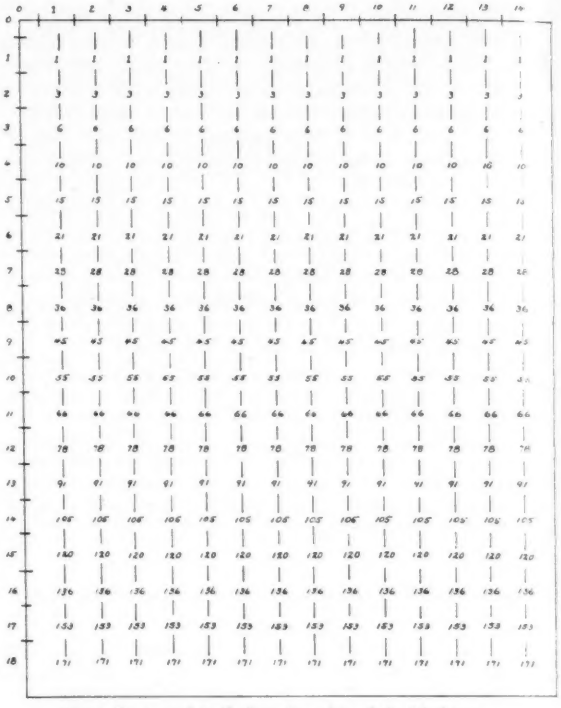


Fig. 5 Sheet used in finding the value of the Y_c factor

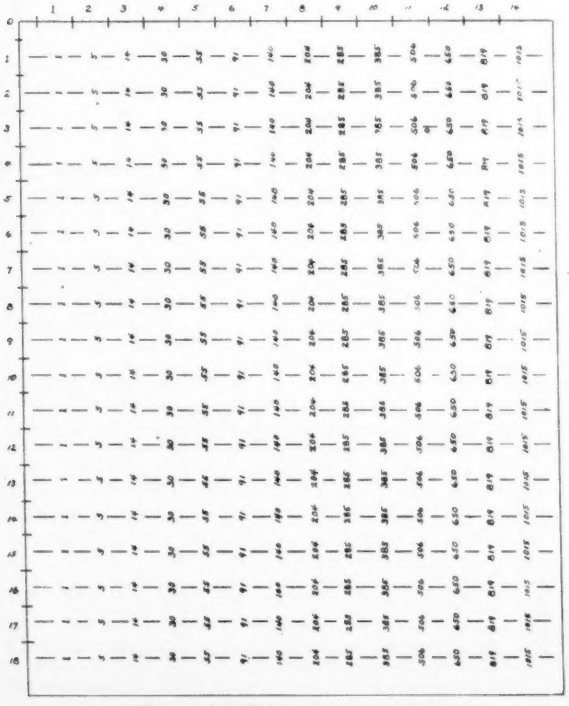


Fig. 6 Sheet used in finding the value of the X^2 factor

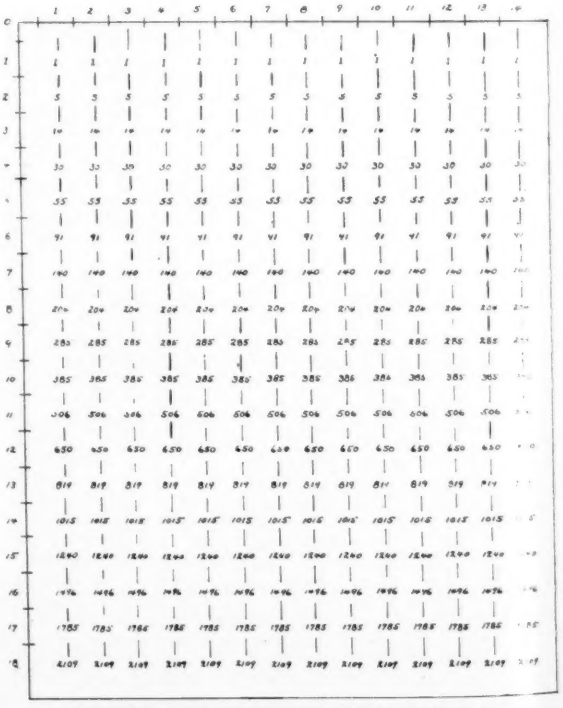


Fig. 7 Sheet used in finding the value of the Y^2 factor

$$\Sigma X^2{}_1 = \Sigma X^2 - nX_c^2$$
$$\Sigma Y^2{}_1 = \Sigma Y^2 - nY_c^2$$
$$\Sigma(XY)_1 = \Sigma(XY) - n(X_cY_c)$$
$$\Sigma(EX)_1 = \Sigma(EX) - n(E_cX_c)$$
$$\Sigma(EY)_1 = \Sigma(EY) - n(E_cY_c)$$

in which X_c and Y_c are rectangular distances from the origin to centroid, n is the total number of elevation points, and E_c is the centroid elevation which is an average elevation for the whole plane and obtained from Fig. 2.

The corresponding values of the above five linear equations are substituted into the two normal simultaneous equations to facilitate their use:

$$(\Sigma X^2 - nX_c^2)S_x + [\Sigma(XY) - nX_cY_c]S_y = \Sigma EX - n(E_cX_c)$$
$$[\Sigma(XY) - nX_cY_c]S_x + (\Sigma Y^2 - nY_c^2)S_y = \Sigma EY - n(E_cY_c)$$

In order to obtain the values of the above variables in the foregoing equations some tables are made up of cumulative values to be used to minimize the amount of calculations.

At the intersection of the X and Y axes we have established a zero origin. This same origin and consecutive stations on the X and Y axes are maintained in all tables.

Fig. 3 is a transparent sheet used as a base to mask out other figures which do not apply to the particular field which is being considered and which has been outlined on said sheet, reduced to one-half size from Fig. 2. This sheet can be used many times for different fields simply by erasing the existing pencil outline.

Fig. 4 is used in finding the value of X_c which is the distance from the Y axis to the centroid. Place the transparent mask or sheet (Fig. 3) on top with rectangular coordinates coinciding. The value of X_c is then obtained in every case by adding the largest figures adjacent and inscribed inside the boundary of field in the direction of the guide lines and subtracting the smaller figures opposite, adjacent, and outside the opposite boundary. For example,

$$(28+28+28+28+28+10+10+10-1-1)/n = 168/45 = 3.733$$

dividing by n or the number of elevations.

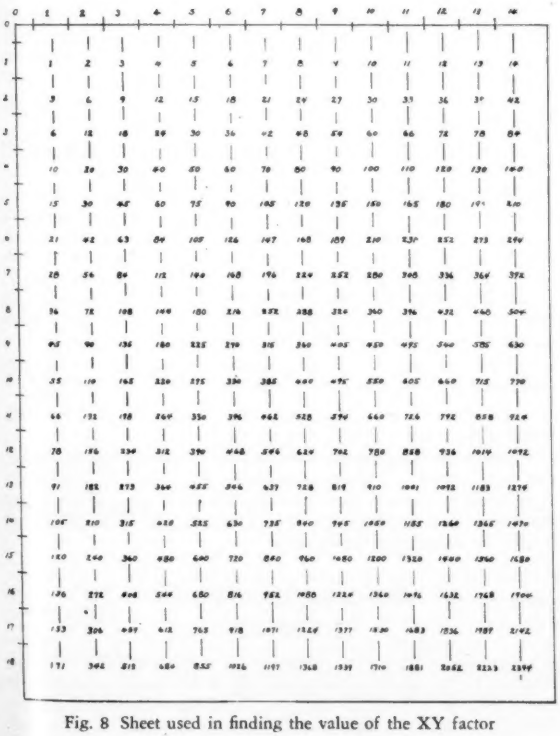


Fig. 8 Sheet used in finding the value of the XY factor

Fig. 5 is used in finding the value of Y_c by also placing the same transparent sheet on top with rectangular coordinates coinciding. The value of Y_c, which is the distance from X axis to the centroid, is then obtained in the same manner as X_c was obtained from Fig. 4. For example,

$$(21+36+36+36+36+36+36-6-6-6)/n = 219/45 = 4.867$$

Fig. 6 is used in finding the value of X^2 by placing the transparent sheet on top and proceeding in the same manner of adding and subtracting as outlined above. For example,

$$140+140+140+140+140+30+30+30-1-1 = 788 = X^2$$

Fig. 7 is used in finding the value of Y^2 by proceeding as for finding value of X^2. For example,

$$91+204+204+204+204+204+204-14-14-14 = 1273 = Y^2$$

Fig. 8 is used in finding the value of XY by proceeding as before. For example,

$$21+72+108+144+180+216+252-30-36-42 = 885 = XY$$

EX is a summation of the column ground elevation totals multiplied by each column's X value taken from Fig. 2. EY is a summation of the column ground elevation totals multiplied by each column's Y value.

Then substitute these values in the equations illustrated by examples:

$$(\Sigma X^2 - nX_c^2)S_x + [\Sigma(XY) - n(X_cY_c)]S_y = \Sigma EX - n(E_cX_c)$$
$$[788 - 45(3.733)^2]S_x + [885 - 45(4.867)(3.733)]S_y = 516.5 - 45(3.404)(3.733)$$
$$160.925\,S_x + 67.395\,S_y = -55.315$$

and

$$[\Sigma(XY) - nX_cY_c]S_x + (\Sigma Y^2 - nY_c^2)S_y = \Sigma EY - n(E_cY_c)$$
$$[885 - 45(4.867)(3.733)]S_x + [1273 - 45(4.867)^2]S_y = 579.6 - 45(3.404)(4.867)$$
$$67.395\,S_x + 207.040\,S_y = -165.915$$

Then solving for S_y,

$$67.395\,[(-67.395\,S_y - 55.315)/160.925] + 207.040\,S_y = -165.915$$
$$S_y = -0.798$$

and solving for S_x,

$$160.925\,S_x + 67.395\,(-0.798) = -55.315$$
$$S_x = -0.010$$

Then to find the origin elevation, $E_o = E_c - S_xX_c - S_yY_c$

$$E_o = 3.404 - (-0.010)(3.733) - (-0.798)(4.867)$$
$$E_o = 7.325$$

Then to find any elevation desired on the plane,

$$E = E_o + S_xX + S_yY$$
$$E = 7.325 - 0.010X - 0.798Y$$

By observing Fig. 2 at each grid corner, the ground elevation (center figure) will be found with grade elevation above, calculated from the foregoing equation, and the cut or fill below shown with minus or plus signs, respectively. The total amount of depth of cut should equal the total amount of height of fill.

To obtain the approximate yardage of cut or fill, square the common distance between grid points and multiply by the total amount of depth of cut or height of fill and divide by 27. For example,

$$(45^2 \times 4.7)/27 = 350 \text{ cu yd (approximately)}$$

Why Not Build Dairy Barns That the Cows Can Pay For?

By B. G. Perkins
MEMBER A.S.A.E.

UNDUE emphasis is being placed on minor items in making comparisons between stanchion barns and loose housing for dairy cattle. Discussions revolve around teat injury, pounds of straw, and other similar items which of course are important, but, frankly, we are making a mountain out of a molehill. Management is *the* important part in handling these items.

The real question of loafing barns versus stanchion barns is mainly one of economics from two standpoints:

1 The *cost* of the *original investment*

2 The *cost* of *operation,* mainly *labor.*

Let us assume that each of you owns a farm. You ask the services of the organization I represent to manage it for you, placing emphasis on profitable operation. You look at the property purely as an investment. Let us assume that we tell you that you need a dairy barn and ask for the cash to build it. Suppose we said to you, "You need a *big* barn, a *fine* one that you can be proud of, a big red barn that will be larger than your neighbors." As owner of the farm, would you not ask, "Will this barn be a good investment? Will the cows using it pay for it and give a good return on the investment?"

Yesterday, on our tour, this group saw a farmer building a "fine" new dairy barn. Do you suppose he calculated the return his cows could make on his investment? This barn was designed to hold 24 cows. The farmer estimated his cash outlay at around $7,000. In addition, there was the cost of all labor. The cash cost alone will be about $300 per cow. Do you know what it will take in production per cow and price of milk to pay for this barn? This farmer will need to have a herd producing on the *average* of 12,000 lb of milk a year and he will have to receive an average price of $2 per cwt for his milk during the life of the barn. There are not many 12,000-lb dairy herds in this country! Some may think $2 for milk is a low price. Do you realize that in 1940 farmers in the state of Wisconsin received as little as $1.40 to $1.50 per cwt?

The other day two of us left this meeting to inspect and obtain the basic data for making a special report on a dairy farm not far from Madison. A 100-ft dairy barn had been struck by lightning and the owner had the problem of replacing his loss. We found two of the finest farms one could see anywhere. The land was all No. 1 soils, 100 per cent tillable — land that produces 100 bu of corn per acre.

In 1929 the owner built a 30-cow dairy barn costing over $9,000 — $300 per cow. His 15-year records on the dairy cattle using this barn, including the high-priced war years, showed that the cows were actually paying off on a capital investment of only $110. Who or what has been paying for this "fine" barn? *The productive land, not the cows!* This is happening throughout the entire dairy industry. Other enterprises are subsidizing our dairy cows because we have not given them buildings they can pay for.

The question is not primarily whether we should build loafing barns or stanchion barns, but *how can we build dairy barns and equipment within the paying ability of the cow?*

Let's look at economy of labor. Let us assume that we are still managing your farm — paying your cash out for labor. Would you, or would you not, want us to consider a system where we might save one-fourth to one-half of your dairy production payroll? Back in the 1920's, our organization took over the management of two 500-cow herds. These cows were moved from stanchions to so-called "milking parlors". Here the payroll was materially cut.

In northeast Ohio we are helping the Westinghouse Electric Corporation to operate a test farm to determine where it is profitable to use electricity on the farm. This farm is in an area where the soil is very poor, the winters are cold with heavy precipitation, and the summers are dry. Nothing is furnished the farmer other than advice and for this he helps keep accurate labor records. The first year's records showed that during the winter months he was putting in 4.66 man-hours per one hundred pounds of milk produced. He was working hard, even his wife and children were helping with the milking. Within three years it has been possible to bring the yearly labor requirements down to 2.68 man-hours per hundredweight. We have set a goal of one man-hour per hundredweight. How can this be accomplished? We know of no other way than by changing from stanchions to a loafing barn with a small milking unit. Perhaps it will take time to accomplish this goal, but at least it is theoretically possible to do even better with the loose housing system.

There are a lot of questions we need to ask ourselves in designing farm buildings. We need to start with the movement of hay from the fields into the barn, to the livestock, and back to the fields in the form of manure. Consideration should be given to every form of work connected with the dairy.

How can we eliminate work and costs in moving hay from the fields to the barn?

How can we eliminate work moving hay from storage to the cows?

Why must we spend good money to support tons and tons of feed above ground when we have the good old earth to set it on?

Why must we climb up into haylofts, lug hay over to the chutes, and poke it down through the chutes with great difficulty when the barn is full? And when the hay is down we still have the job of distributing it to the cows.

Why not go from storage directly into the feed manger the full length of the barn?

How can we eliminate the daily time-consuming job of removing manure?

How can we best make use of the fertilizer? Why not make a "fertilizer factory" out of our barns? (If you will calculate the value of extra bushels of corn, bushels of oats, extra tons of hay and other crops obtainable over a good rotation calculated at prewar prices of 50c corn, 30c oats, and $5 to $8 hay obtainable from the extra manure produced from the loose-barn system, you will find that it will amount to about $300 a year for a 20-cow herd.)

How can we cut labor requirements in half so farmers will have time to enjoy the pleasures of their city friends?

How can we cut the costs so the farmer can pay for these pleasures?

Agricultural engineers have a real responsibility to American agriculture — a responsibility to farmers. We must design barns within the ability of the livestock using them to pay for them and at the same time increase the labor efficiency. It can be done; it must be done.

Contribution to a round-table discussion at the Dairy Housing Conference sponsored by the Farm Structures Division of the American Society of Agricultural Engineers at Madison, Wis., July, 1947.

B. G. PERKINS is specialist in farm management, Doane Agricultural Service, Inc.

"Designing Plywood Silos"
A Correction

Attention was called recently to a transposition of illustrations in the above-titled article by J. D. Long appearing on pages 189 to 194 of AGRICULTURAL ENGINEERING for May, 1947. The cuts for Figs. 1 and 4 were transposed as published.

Remember!

Interior-Type Douglas Fir Plywood Now Manufactured With High-Performance Adhesive

. . . As Outlined in New U.S. Commercial Standard CS 45-47

NEW STANDARDS of performance and serviceability are now incorporated in every panel of Interior-type Douglas fir plywood. U.S. Commercial Standard CS 45-47—newly adopted by the Douglas fir plywood industry—sets up a higher quality standard than ever before. Two principal improvements have been made in all Interior-type plywood: (1) Every panel is now manufactured with higher performance adhesive (the premium adhesive long used in Plyform grade); (2) Every panel is manufactured with higher specification inner plys.

And remember, too, that this improved Interior-type Douglas fir plywood is now manufactured in these specific grades:

PLYPANEL
Sound 1 Side

A general-purpose Interior-type panel for applications where only one surface is to be exposed. Plypanel Sound 1 Side (So1S) replaces two former grades—both Plywall and the old So1S grade.

PLYPANEL B.E.P.A.—So2S

PLYPANEL
Sound 2 Sides

For applications where both surfaces are exposed (cabinets, cabinet doors, booth partitions, etc.)

PLYSCORD

An unsanded panel manufactured specifically for wall and roof sheathing and subflooring.

PLYFORM

Manufactured with the time-tested and proved premium adhesive which has now been adopted for all Interior-type Douglar fir plywood. Plyform is a structurally stronger panel, made especially for multiple re-use concrete forms.

● **For Permanent Exposure to Weather, Water or Abnormal Moisture Conditions . . . Specify**

EXTERIOR-TYPE Douglas Fir Plywood

EXT.-D.F.P.A.

Exterior-type Douglas fir plywood—available in several appearance grades*—should be specified for all permanent exposures to weather, water and abnormal moisture conditions. Higher specification inner plys are now used in Exterior-type Douglas fir plywood—as called for in the new U.S. Commercial Standard CS 45-47. Exterior-type is still manufactured with the same high performance, completely waterproof phenolic resin adhesive which makes this type of plywood so ideal for all outside construction use, for marine applications and for unusual use conditions such as are encountered in the lining of refrigerator cars.

★*An example is Sound 1 Side Exterior—the grade generally used for the exterior siding of homes and commercial buildings.*

WRITE FOR YOUR COMPLETE COPY OF THIS NEW COMMERCIAL STANDARD

Booklets giving complete data on the new U.S. Commercial Standard (CS 45-47) for all types and grades of Douglas fir plywood are available. Single copies will be mailed without charge to any point in the United States. Address your request to: Douglas Fir Plywood Association, Tacoma 2, Wash.

Douglas Fir PLYWOOD

LARGE, LIGHT, STRONG

***Real Wood* Panels**

RESEARCH NOTES

A.S.A.E. members and friends are invited to supply, for publication under this heading, brief news notes and reports on research activities of special agricultural engineering interest, whether of federal or state agencies or of manufacturing and service organizations. This may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Mich.

INSECTICIDE AND FUNGICIDE MEETING

MORE effective and efficient control of economic insects and diseases through closer understanding of the mutual problems of chemical producers, application equipment manufacturers, and federal and state experiment stations was the objective of a meeting at Toledo, Ohio, September 11 and 12, of the Agricultural Insecticide and Fungicide Association's application equipment committee. Representatives of chemical and equipment companies met with USDA agricultural engineers, entomologists, and plant pathologists to bring together specific problems and clarify research needs. A. W. Turner made the initial address.

L. S. Hitchner, executive secretary of the A.I.F.A. pointed out that we now have new chemicals for which improved equipment is needed and we have new pests requiring new pesticides. There are physical characteristics of the new insecticide and fungicide materials, such as abrasiveness, of which we know little. Applying the new poisons sometimes creates new hazards for the operators. Further research is needed on toxicity to plant life and dangers to bees, livestock, and wildlife. Careless use of these pesticides might subject the industry to unnecessary criticism.

Avoidance of drift was a major concern emphasized at the meeting. Several speakers stressed the importance of developing equipment to put the new chemicals exactly where they are wanted. Plant-disease control requires more exact and complete coverage than insect control because of the immobility of spores once they alight on a plant. The 8,000 pests in the United States require various poisons and methods of application. The new synthetic insecticides are more potent than some of the old ones. Consequently they require more diluent and precise application.

Committee members visited the pest and plant disease control equipment project, of which Frank Irons is the USDA agricultural engineer in charge, and saw many types of apparatus, a number of them in operation. Included were hydraulic sprayers for corn borer control, the Besler aerosol generator, the Niagara duster with tilted canopy for corn borer control, the Buffalo turbine with USDA broadcast nozzle, and the USDA self-propelled experimental duster and sprayer.

Airplane spray booms with nozzles and airplane duster venturi and apparatus were on display, with O. K. Hedden on hand to explain their operation. Irons showed the visitors equipment to mix and spread grasshopper bait. David Isler explained the aerial spray equipment for forest insect control and the nozzle test for particle size. A. H. Glaves demonstrated duster test technique and apparatus for feed control, distribution, and fractionation, an adapter tube for air volume control and a velometer for velocity, duster nozzles, dust mixing, dust apparent density measure, dust abrasion apparatus, and the dust fractionation tunnel. C. A. Batchelder of the Bureau of Entomology and Plant Quarantine called attention to the corn borer exhibit and explained aerial deposit color determinations and work on spray particle size.

* * * *

COTTON MECHANIZATION CONFERENCE

The August conference at Stoneville, Miss., sponsored by the National Cotton Council of America in cooperation with the Farm Equipment Institute, the USDA, land-grant colleges, and farm organizations, had the specific title, "Increasing Income of Farm Workers of the Cotton Belt Through Mechanization of Cotton and Related Crops." Outstanding leaders enunciated a hopeful point of view on this question and brought to light information on the present status of mechanization and current trends in its development.

Oscar Johnson, president of the National Cotton Council, who operates Scott plantation in Mississippi, largest single cotton-producing enterprise, reminded his hearers at the conference that mechanization always represents progress. Although the grain combine raised the cry that farm workers in the grain belt were doomed to economic slavery, workers of that broad area have achieved greater prosperity than was ever possible under the old system. Introduction of power-driven spinning and weaving machines caused fear that workers in the cotton textile industry would go hungry for lack of employment, but these important devices formed the very basis for the industry's great growth. Johnson sees mechanization in cotton as the result rather than the cause of population shifts.

Essentially the same view was expressed at the conference by J. L. McCaffrey, president of the International Harvester Co. He stated that the economic history of America has proved that everyone benefits from the development of mechanical processes of production which make it possible for fewer people to do more and better work.

While cotton production on large-scale enterprises in the flat lands of the Far West, the Delta, and even the Georgia flat land, the Coastal Plain, and the Arkansas Valley is going in the direction of complete mechanization, it was brought out that much top-quality cotton will be produced for a long time to come partly by machine and partly by hand on small hill farms. Development of equipment for the small farmer in the South will come as the demand grows and new machines will be adapted for use on cotton and also on other crops, as the importance of diversification in the economy has been firmly established.

* * * *

COTTON MECHANIZATION RESEARCH PROGRAM ANNOUNCED

Development of efficient equipment for mechanizing cotton production in the South is the object of a new regional research program announced by the U. S. Department of Agriculture. The program will be part of the work to be carried on in the Department's Agricultural Research Administration under the 1946 Research and Marketing Act.

Emphasis in the new program will be on equipment for producing and harvesting cotton on small farms. The aim also is to improve such equipment for use on larger operations. A special phase of the project will be development of uniformly dependable methods and equipment for defoliating cotton prior to harvesting throughout the cotton belt.

The cotton mechanization studies will be carried on in a number of southern states by the Bureau of Plant Industry, Soils, and Agricultural Engineering in cooperation with the state agricultural experiment stations. Agricultural engineers of the Bureau's Division of Farm Power and Machinery will be responsible for the development of satisfactory growing, harvesting, and other equipment, and the Division of Cotton and Other Fiber Crops and Diseases will have charge of the plant investigations.

The new studies will include investigations of equipment and methods for seedbed preparation, delinting of cotton seed for planting, weed control, application of insecticides and fungicides for pest and plant disease control, and improvement of existing harvesting equipment.

In approving the project E. A. Meyer, administrator of the research act, pointed out that cotton growers are faced with greatly increasing competition from foreign cotton and synthetic fibers. Reductions in costs of production and harvesting are needed to meet this competition and can be affected mainly by greater use of suitable machines. Mechanization of small farms with 20 acres or less in cotton, mostly on rolling hillsides, he said, depends on development of equipment suitable for operation under these conditions.

* * * *

OTHER RESEARCH AND MARKETING PROJECTS

Other projects being initiated under the Research and Marketing Act of 1946 were announced last month by the USDA, and more announcements are expected to follow. Although not primarily the responsibility of the agricultural engineers, some of these new lines of research have important agricultural engineering implications.

An example is the project for development of methods to process meat so as to prevent deterioration in quality and nutritive value during processing, storage, and distribution. Plans include tests on samples of meat that have been processed by methods now used by packers, freezer locker plants, curing plants, and farmers to determine the effect of these methods on flavor, tenderness, juiciness, color, and bacterial and mold content. With this knowledge as a basis work will then proceed in an effort to develop processing methods that will more effectively preserve the food value and palatability of meats.

Of broader engineering interest in the work to be carried on by the Forest Service, largely at the Forest Products Laboratory, Madison, Wis., on development of new and increased uses for farm-grown timber and ways to get better service from wood products made from such timber. Several specific types of activity are contemplated under this project, with objectives including improvement in methods of using lumber from woodlots in farm buildings; developing and testing equipment that will permit farmers to get their own logs converted into a more finished type of lumber; improved chemicals and ways of applying them to preserve posts and other timber produced and used on the farm; determining possibilities for making pulp from farm-grown northern and southern hardwood species and suitable outlets for pulp and paper; better paints and painting practices for farm structures; and new small-scale methods for hydrolyzing wood in the production of molasses and yeast for livestock feed.

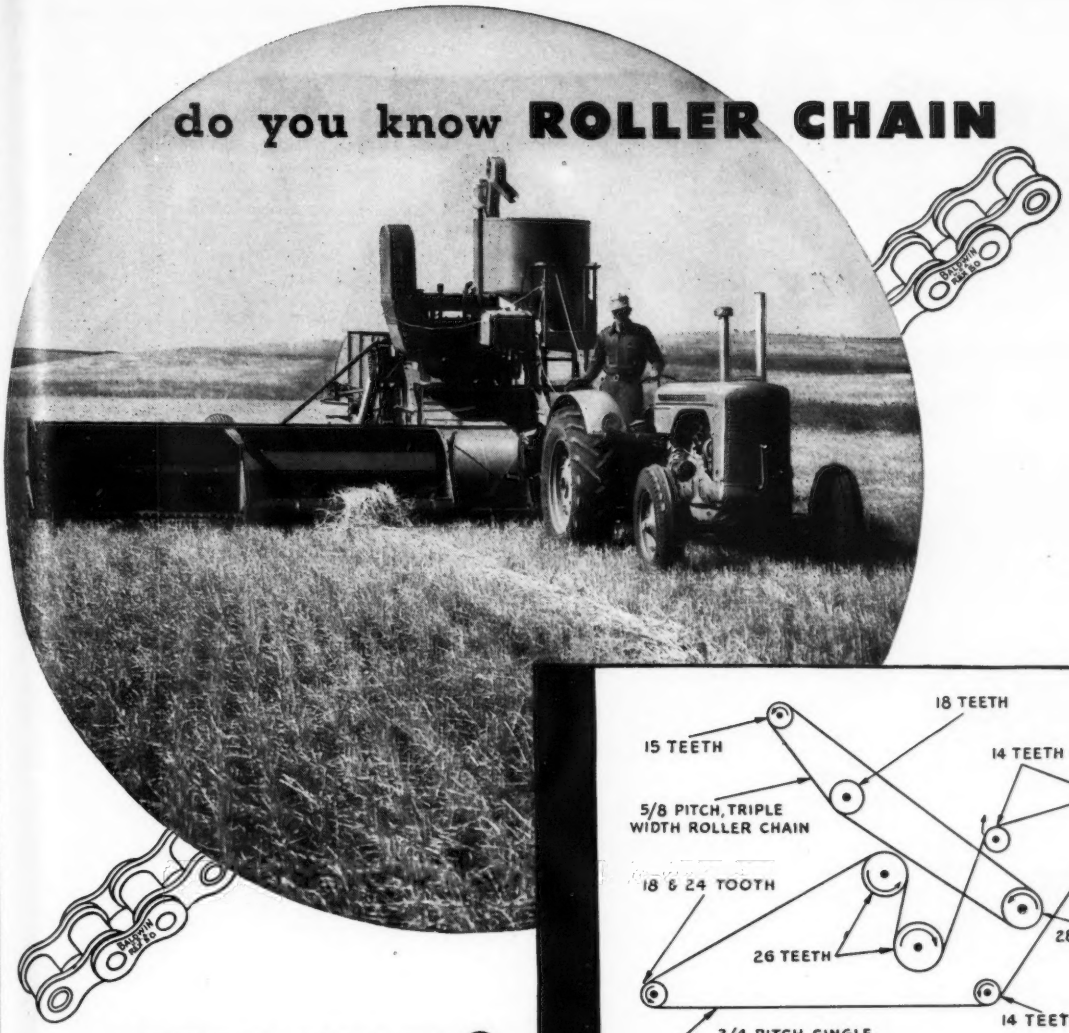
* * * *

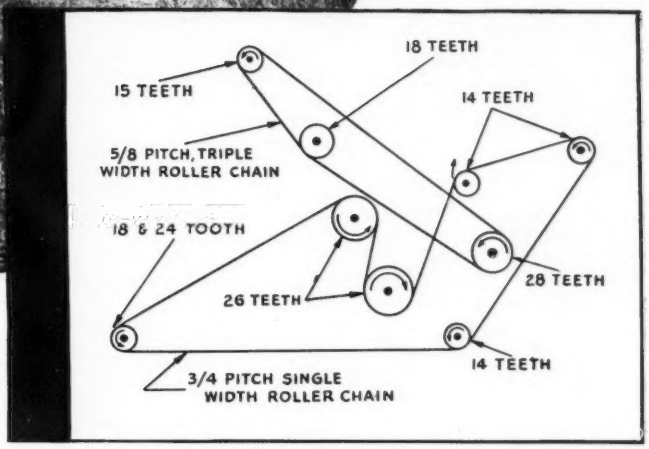
EQUIPMENT CONFERENCE AT WISCONSIN

The Wisconsin Agricultural Experiment Station and the Farm Equipment Institute held an agricultural equipment research conference on September 11 and 12 which brought together specialists from several University departments and prominent companies to discuss dairying and grassland agricultural problems and developments, particularly with respect to farm equipment. The program covered topics ranging from soil conservation to human and animal nutrition.

(Continued on page 472)

do you know ROLLER CHAIN





. . . saves space?

For example, on this combine the proper application of Baldwin-Rex roller chains for engine and feeder drives permitted the saving of considerable space. As the drive arrangement diagram indicates, only one chain is used to drive six sprockets . . . an application that would be extremely difficult for other types of power transmission equipment.

And, as an example of the versatility of roller chain, note that the ability of the chain to flex in two directions is employed to rotate shafts both clockwise and counter-clockwise. Note, too, the comparatively small size of the sprockets, an indication of the fact that roller chains can transmit more horsepower in less space.

And, in addition to their ability to save drive space, roller chains also save space on dealers' shelves. There is no need to stock 60 or 70 different sizes of chain . . . 5 is usually plenty. Remember, for economy, long life, dependability, and high production, roller chains are the best farm equipment drive.

BALDWIN·REX
ROLLER CHAINS

Write for complete information on roller chains and for specific data on your drive installation problems. There is no obligation.

BALDWIN-DUCKWORTH DIVISION OF CHAIN BELT COMPANY
376 Plainfield Street, Springfield 2, Massachusetts

TIME

PROVES

Galvanized (ZINC-COATED) Sheets Stay Stronger Longer

34 YEARS . . . Erected in 1913, and covered with heavy gauge galvanized sheets, this Tennessee concentrating plant of the A/Z Company, pictured at left, is still in excellent condition after more than three decades of service. Painted with Gray Metallic Zinc Paint in 1932.

50 YEARS . . . The galvanized metal roof on this old Missouri farm building has outlasted the building itself, and is still in good condition after half a century of service. Industry and the farm have long depended on galvanizing to protect iron and steel against costly rust. Builders know that as long as iron or steel is zinc covered, it *cannot rust.*

In building for the future, look to the past for proof of a building material's strength . . . durability . . . service. With *galvanized* (zinc-coated) roofing and siding you get the strength of steel . . . the rust protection of Zinc. So for low-cost, long-time service choose the building material that's proved by TIME itself . . . galvanized sheets. Send coupon for information about Zinc and how it helps keep buildings and equipment *stronger longer.*

ZINC INSTITUTE 2 OZ. COATING SEAL OF QUALITY

This "Seal of Quality" is your guide to economy in buying galvanized sheets. Sheets bearing it carry at least 2 oz. Zinc per sq. ft.

American Zinc Institute

ROOM 2619 • 35 E. WACKER DRIVE, CHICAGO 1, ILL.

FREE BOOKLETS!

Send me without cost or obligation the illustrated booklets I have checked.

- ☐ Repair Manual on Galvanized Roofing and Siding
- ☐ Facts about Galvanized Sheets
- ☐ Use of Metallic Zinc Paint to Protect Metal Surfaces

Name_____

Address_____

Town_____ State_____

NEWS SECTION

A.S.A.E. Meetings Calendar

October 23 and 24—PENNSYLVANIA SECTION, Agricultural Engineering Bldg., Pennsylvania State College, State College, Pa.

October 23 and 24—PACIFIC NORTHWEST SECTION, Davenport Hotel, Spokane, Wash.

December 15 to 18—FALL MEETING, Stevens Hotel, Chicago.

June 20 to 23—ANNUAL MEETING, Multnomah Hotel, Portland, Oregon.

A.S.A.E. Fall Meeting Program

SESSIONS of all four technical divisions of the American Society of Agricultural Engineers have been scheduled for the fall meeting to be held at the Stevens Hotel, Chicago, December 15, 16, and 17.

It appears probable that the Rural Electric and the Soil and Water programs will open the meeting Monday forenoon, December 15, and continue through all or part of the following day. The Power and Machinery and the Farm Structures programs are to start Tuesday, December 16, and continue through the following day.

Some of the power and machinery men will be occupied Monday with the related meeting of the National Joint Committee on Fertilizer Placement, on which the A.S.A.E. is represented.

Dehydration, with particular emphasis on grain and corn drying, and possibly some attention to drying forage crops, is to be featured on a joint program of the Farm Structures and Rural Electric Divisions on Tuesday, December 16.

A number of other special interests are scheduled to be featured in half-day sessions. On the Power and Machinery program are these subjects: "Flexible Power Transmission for Farm Machines," "Direct Engine-Driven Power Take-off," "Should Farm Machines be Self-Propelled," and "New Farm Machines."

These subjects, "Drainage," "Upstream Flood Control," "Hydrology," and "Soil Conservation," are on the preliminary Soil and Water Division program.

"New Developments in Farm Wiring," "Increased Productive Efficiency through Electrical Equipment," and "Uses of Radiation in Agriculture" are additional program topics of the Rural Electric Division.

In addition to the joint program on drying, the Farm Structures Division has scheduled a program on "Application of Building Materials," and a group of papers on design with specific reference to combined structures, hog farrowing facilities, milk houses, grain bin floors, and dairy and beef cattle barns. Construction economy and labor efficiency are to be emphasized in several of these papers.

A block of 350 rooms has been set aside by the Stevens Hotel for reservation requests from A.S.A.E. members and visitors. Assignment to these rooms is being made in the order in which requests are received.

Pacific Northwest Section Meeting

A TWO-DAY meeting of the Pacific Northwest Section of the American Society of Agricultural Engineers is scheduled for Thursday and Friday, October 23 and 24, at the Davenport Hotel, Spokane, Wash. It opens with a half-day general session Thursday forenoon, followed by concurrent sessions on power and machinery, rural electrification, soil and water, farm structures, and student interests during the afternoon and evening. General sessions make up the program for Friday.

Attention in the opening general session is to be given to the following subjects: "Some Aspects of Forage that Need Engineering Research," "The Role of the Engineer in Soil Conservation in the Northwest," "Agricultural Uses of the Helicopter," and "Ninety Years of Western Tractors."

General session subjects scheduled for Friday include "Trends in Structures for the Dairy Enterprise," "Washington State Ground Water Code and Its Administration," "Economic Implications of Reclaiming and Settling New Lands," "Test of the Arnold Drier," and "The Development of Rural Electrification in the Northwest."

The separate power and machinery session will feature weed control, flax production, small tractors, and mechanization in the Columbia Basin.

Rural electric interests scheduled for attention are germicidal and infrared lamps, single and three-phase power, refrigeration, and problems in rural electrification.

A symposium on sprinkler irrigation and a round table on irrigation development have been planned for the specific interest of the soil and water group.

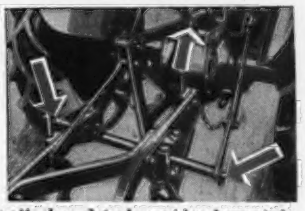
The farm structures program provides attention to farm homes, silos, models, prefabrication, and a farm building plan service.

The meeting will close with a business session following the general session Friday afternoon, and the section dinner Friday evening.

(News continued on page 470)

SAVES TIME HERE TO USE IN THE FIELD

FORD TRIPLE-QUICK ATTACHING



You can attach or detach most implements in a minute or less. Arrows above show 3-point, triple-quick attachment. Even such a job as changing from mower to cultivator, or cultivator to mower, is easily done in 10 minutes.

LIFTS, LOWERS AND CONTROLS IMPLEMENT IN THE GROUND AT THE TOUCH OF A FINGER

FORD HYDRAULIC TOUCH CONTROL

Includes constant draft feature

Lifting or lowering of implements is handled anywhere at any time without effort, just by touching the hydraulic control lever. An implement can be lowered to desired working depth and under uniform soil conditions, this depth will be automatically maintained.

MAINTAINS UNIFORM DEPTH UNDER VARYING SOIL CONDITIONS

FORD HYDRAULIC TOUCH CONTROL

Includes implement position control

This great new Ford advancement means smoother operation, less wear on tractor and driver, easier, better work. In fields with reasonably smooth surfaces all you do is set the controls once—and uniform working depth of implements is automatically maintained, even when soil conditions vary.

Quick, Easy Attachment of Implements *Plus* Ford Hydraulic Touch Control

ADD UP TO FASTER, EASIER FARMING

There will always be plenty of work to do on any farm . . . but there's no reason why as much of this work as possible shouldn't be made as fast and easy as possible.

Your Ford Tractor dealer invites you to examine this new tractor and the many Dearborn quality implements that have been designed especially to work with it. He'll be glad to demonstrate both tractor and implements to you.

We think you'll agree that your farm work *can* be made faster, easier and more productive—the new Ford Tractor way.

Dearborn Motors Corporation **Detroit 3, Michigan**

Dearborn
FARM EQUIPMENT

SEE YOUR DEALER. Your nearby Ford Tractor dealer asks you to remember that he is headquarters for genuine Ford Tractor parts and for implement and tractor service second to none. He is a good man to know.

COPYRIGHT 1947, DEARBORN MOTORS CORPORATION

Ford Farming MEANS LESS WORK . . . MORE INCOME PER ACRE

Concrete can't burn!

Design firesafety into farm buildings with CONCRETE

AS AGRICULTURAL engineers well know, farm buildings are at the mercy of fire unless they are of firesafe construction. The National Fire Protection Association estimates annual farm fire loss at $85 million. Farm barn fires alone number over 16,600 annually.

Concrete's firesafety makes it the logical farm building material. Other important advantages include moderate first cost, low upkeep, and lifetime service. Concrete can't decay. Rats can't gnaw through it. Concrete walls and floors are easily kept clean and vermin-free.

Free illustrated literature is available to assist agricultural engineers in designing and building firesafe concrete dairy barns, milk houses and many other profitable farm structures. Distributed only in United States and Canada.

PORTLAND CEMENT ASSOCIATION

Dept. A10-1, 33 W. Grand Ave., Chicago 10, Illinois

A national organization to improve and extend the uses of portland cement and concrete . . . through scientific research and engineering field work

NEWS SECTION

(Continued from page 468)

Farm Electrification Manual

THE Edison Electric Institute's "Farm Electrification Manual", designed to serve as a technical handbook for electric company rural representatives, cooperative managers and others engaged in farm electrification work, and now being distributed to purchasers, is prepared in section form, with each section covering a major farm use of electricity and written by an outstanding authority in each field. A committee of 25 leading farm electrification specialists, located in every part of the country, reviewed each section and made suggestions that were incorporated in the final drafts.

A total of seven sections — on the rural representative and his job, history of farm electrification, farm lighting, mow curing of hay, farmstead wiring, and a directory of manufacturers of farm electrical equipment—are at present available. Seven additional sections are now in preparation and will be released shortly.

The practical information on farm applications of electricity, with many illustrations and diagrams of wiring arrangements, installation methods for electrical equipment, etc., is expected to make the manual of use to the rural representative in almost every customer contact. The actual preparation of the manual was accomplished by a committee of the E.E.I. Farm Section under the chairmanship of John L. Burgan of the New York State Electric & Gas Corp.

Copies of the Farm Electrification Manual may be obtained from Edison Electric Institute, 420 Lexington Ave., New York 17, N. Y. The price, which includes a binder and total of 14 sections, is $5.00 per copy to E.E.I. members and $8.00 to non-members.

Farm Structures Study Completed

MORE than 30 agricultural engineers attended the "Farm Structures Conference and Training Course", a four-day advanced refresher and new development study sponsored jointly by the American Society of Agricultural Engineers and the College of Agriculture, University of Illinois. The Conference was held at Urbana, Ill., September 15 to 18 inclusive.

Special attention was given in the program to farm housing and to crop storage and conditioning. Planning was a major item, with labor efficiency, electrification, and evaluation related to structural features and arrangement. Public service extension and commercial trade promotion means of influencing farm building practice were also presented.

Those attending included farm structures men with the colleges, field men in the building materials and equipment industry, and others with varied interests, including editors, designers, and trade promotion men.

E. W. Lehmann, D. G. Carter, K. H. Hinchcliff, R. C. Hay, J. H. Ramser, and R. W. Whitaker of the agricultural engineering staff of the University of Illinois, and Thayer Cleaver and L. E. Holman of the USDA, were the agricultural engineers on the program, along with representatives of various other departments at the University.

RESEARCH NOTES

(Continued from page 466)

F. W. Duffee, chairman of the agricultural engineering department at the University of Wisconsin, presided at the opening session. Floyd Andre, assistant director of the experiment station, gave a summary of the station's research with special reference to projects having farm equipment implication. Field crop research with special reference to equipment aspects was discussed by H. L. Ahlgren, pasture research specialist, and M. L. Jackson of the soils department talked on soil tillage and tilth. Agricultural engineer A. J. Wojta explained the need for research in adapting field machinery to soil conservation practices, and needed improvements in farm equipment were pointed out by O. I. Berge, extension agricultural engineer.

The afternoon session included talks on fertilizer application by E. Truog, chairman of the soils department, and chemical weed control by K. P. Buchholtz, agronomist, as well as visits to mow hay drying installations, the dairy barn research project, and ensilage harvesting on the Hill Farm. Sessions the following day were equally instructive. Considerable interest was shown in discussions of hay making and curing methods, insect control with special reference to the European corn borer, farmstead mechanization, and an exposition of Wisconsin's grassland agricultural program. A summary of the conference is being prepared and can be obtained from the Wisconsin station.

New Literature

Farm Labor Savers, compiled by Robert L. Crane. Paper, 116 pages, 6x9 inches. Lithoprinted. Illustrated. Farm Labor Savers, Box 5023, Chicago, Ill. Price, $1.50 postpaid.

One hundred equipment items from airplanes to windrow attachments, with brief description of farm applications, and lists of manufacturers. Useful as a check list for both new and experienced farmers considering investment in additional labor-saving equipment.

Operates Tractors WITHOUT DRIVERS

Speeds Field Work Cuts Labor Cost

One man keeps two or three tractors going—saving work-time and labor expense

Mr. F. O. Masten, prominent rancher of Sudan, Texas, who operates over 40,000 acres, has found that one man can keep a "herd" of tractors working in the field at a saving in time, labor and expense. When plowing, the "guides" are set so that the tractor moves in spirals. When the edges of the field are reached, the tractors are manned and the corners plowed.

For this "robot" operation, equipment has to be carefully adjusted and well lubricated. Mr. Masten says: "I find by using Texaco Marfak and Havoline Motor Oil I get the best results."

Mr. F. O. Masten points to disk "guides" that keep tractor in furrows. Sam Fox, popular Texaco Man of Muleshoe, Texas, is an interested observer.

Picture shows one of Mr. F. O. Masten's "driverless tractors" moving down the field. Action is indicated by dust around cultivator shovels.

In the great Corn Belt too, leading farmers like Mr. O. E. Everson, Whiting, Ia., find it pays to farm with Texaco products. Mr. Everson is getting a delivery of Fire-Chief, the gasoline with superior *"Fire-Power,"* from smiling Joe Stangel, of Stangel Bros., popular Texaco distributors of Onawa.

New FREE Texaco Service: Mr. L. D. Patton, of Texaco, shows Mr. C. J. Carlson, farm machinery inventor of Marshalltown, Ia., Texaco's new lubrication "Bible". Don Dobson (center) has Special Lubrication Tag for tractor that tells when lubricants are needed and kind and grades to use. *Get tags for your tractors from your local Texaco Man.*

Tune in: TEXACO STAR THEATER presents the TONY MARTIN show every Sunday night. See newspaper for time and station.

IT PAYS TO FARM WITH TEXACO PRODUCTS

THE TEXAS COMPANY

DIVISION OFFICES: Atlanta 1, Ga.; Boston 17, Mass.; Buffalo 3, N. Y.; Butte, Mont.; Chicago 4, Ill.; Dallas 2, Tex.; Denver 1, Colo.; Houston 1, Tex.; Indianapolis 1, Ind.; Los Angeles 15, Calif.; Minneapolis 2, Minn.; New Orleans 6, La.; New York 17, N. Y.; Norfolk 1, Va.; Seattle 11, Wash.

Texaco Products also distributed by McColl-Frontenac Oil Company, Limited, Montreal, Canada

One of the strongest selling statements that can be made regarding any engine-powered equipment is this:

"It's Powered with a FORD-BUILT ENGINE!"

Engines available through district sales offices of Ford Motor Company or through Ford Dealers. Universal Ford Service always available everywhere.

Ford

FOURS · SIXES · V-EIGHTS

Write For Latest Industrial Literature

Address:

FORD MOTOR COMPANY

Industrial and Marine Engine Department

3519 SCHAEFER ROAD · DEARBORN, MICHIGAN

1492

When Columbus came, there were NO wheels in the western world.

1888

When French & Hecht originated the modern metal wheel, the speed and weight limitations of the wooden wheel were overcome.

1947

Millions of the finest implements, tractors, and wagons in agriculture and industry are safely mounted on —

WHEELS "by French & Hecht"

Mobile equipment is only as strong as the wheels upon which it is mounted. We know how to design, test and produce wheels capable of meeting the responsibilities entrustd to them. Specify WHEELS "by French & Hecht" with confidence.

Send Your Wheel Problems to Us

FRENCH & HECHT

DIVISION

KELSEY-HAYES WHEEL COMPANY

DAVENPORT, IOWA

Wheel Builders Since 1888

Personals of A.S.A.E. Members

John F. Cykler has resigned as agricultural engineer, Wyoming Agricultural Experiment Station, to join the staff of the University of Hawaii's recently organized Agricultural Engineering Institute at Honolulu.

Roy W. Godley has resigned as rural sales manager of the Edison Electric Institute, to become agricultural counsel for the Kroger Company, 35 East Seventh Street, Cincinnati, Ohio.

Robert L. Green has resigned as assistant soil conservationist, Soil Conservation Service, USDA, Lawrenceville, Ga., to accept appointment as assistant professor of agricultural engineering at Louisiana State University.

Gordon L. Nelson has resigned as senior agricultural engineer, Portland Cement Association, to accept a position on the agricultural engineering staff of the Oklahoma A. & M. College, where his principal activity will be research in the field of farm structures.

Harris P. Smith, in charge of agricultural research, A. &. M. College of Texas, is author of an article, entitled "The Production of Cotton in the United States" which appeared in "The Empire Cotton Growing Review", of London, England, for July, 1947.

T. E. Thoreson has resigned as a farm specialist for the General Electric Supply Corp. at Milwaukee, to accept a teaching position in the farm mechanics department at the River Falls State Teachers College at River Falls, Wis.

Fred A. Wirt, advertising manager, J. I. Case Co., and a past-president of A.S.A.E., was a luncheon speaker during the 26th Conference of the American County Life Association at Dubuque, Iowa, in June. His subject was "The Place of Soil Conservation in the Development of a Rural Philosophy."

Industrial Utilization of Straw

TO THE EDITOR:

THAT industrial utilization of straw is receiving renewed attention is indicated by the two articles on this subject in AGRICULTURAL ENGINEERING for July ,1947. While attention so far appears to be largely from the industry viewpoint, and more attention should be given the agricultural aspects. Farmers' interests may well be overlooked by farmers themselves, and as a matter of professional responsibility, agricultural engineers might well appraise the problem with a view to all interests concerned.

For the economic sale of straw for commercial uses, it is necessary (1) that the sale net the farmer more than the straw's value on the farm, and (2) that its critical need on the farm can be met by other means.

There may be a tendency to underestimate the direct fertility value of straw and also to overlook its role in the maintenance of soil structure.

The following data indicate the possible direct fertility value of straw when returned to the land:

YIELDS, COMPOSITION, AND ESTIMATED VALUE PER ACRE OF STRAW ON EXPERIMENTAL WATERSHEDS, PURDUE-THROCKMORTON FARM, LAFAYETTE, INDIANA, 1945

Watershed No.	Treatment	Yields, lb	Total content, lb N	P_2O_5	K_2O	Estimated Value
4	Prevailing	4,557	44	6	44	$7.45
12	Prevailing	4,877	47	6	47	7.93
2	Conservation	6,966	134	13	135	22.36
11	Conservation	7,326	141	13	142	23.46

Yield determination and chemical analyses of straw by G. D. Bedell, soil scientist, U. S. Soil Conservation Service (Research).

The conservation treatment substantially increased the weight of straw and also greatly influenced its composition. Assuming that the fertility content of the straw returned to the land may eventually be recovered for crop production as efficiently as from commercial fertilizers, the average values of the straw left in the field were $6.43 and $3.23 per ton, respectively, for the conservation and prevailing treatment of the land (based on 1947 prices at Lafayette, Indiana).

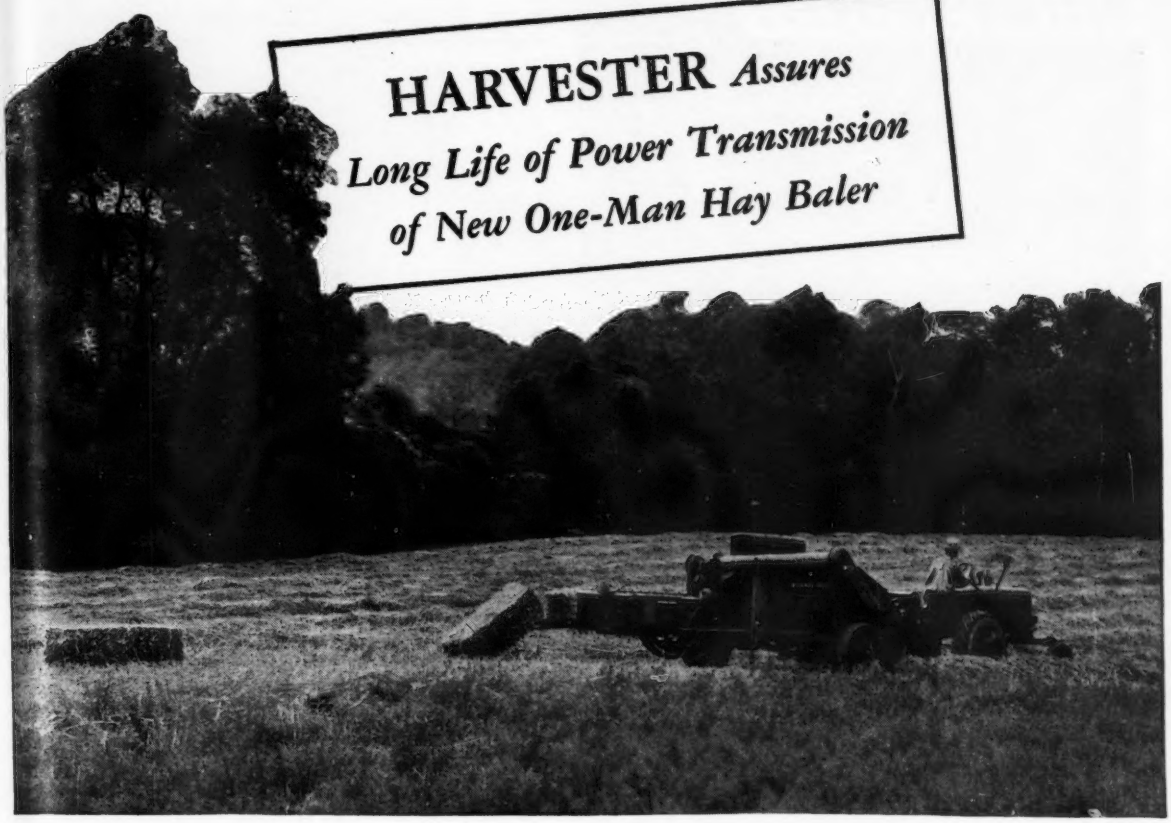
Present agricultural practices in the Midwest are permitting a general depreciation in soil structure and soil-water relationships, with increasing runoff and erosion. To reduce the amounts of straw being returned to the land would be to accelerate the trend, unless the straw might be replaced by other crop residues. It seems doubtful that such a substitution could be made without adding to the cost of removing the straw.

I seriously question that straw removal would automatically result in sufficiently increased meadow growth to offset the straw removal, or that such increased growth of meadows would be apt to be returned to the land. Rather, I believe that any increase in hay produced might also be sold with a resulting doubly increased drain of fertility and organic matter off the farms from which straw was sold.

R. B. HICKOK

Project supervisor (research)
Soil Conservation Service, USDA

HARVESTER *Assures Long Life of Power Transmission of New One-Man Hay Baler*



Think of 3 to 5 bales a minute coming from this automatic, self-tying twine baler . . . with only one operator . . . the man on the tractor which pulls the machine.

Moreover . . . to assure long, low-cost performance . . . the maker, International Harvester Company, built this one-man pickup baler with numerous wearing parts made of case-hardened Nickel-chromium-molybdenum steel.

Carburizing grades of triple alloy steels containing Nickel make hard, uniform wear-resistant surfaces backed by strong, tough cores. Gears made from these steels have *extra* stamina to withstand shock loads, high tooth pressures and other severe stresses.

We invite consultation on use of Nickel alloy steels. Send details of your problem to obtain our recommendations.

This baler is operated by a 4-cylinder 14-h.p. engine. Although designed for windrow pickup baling, this labor-saving unit known as the No. 50-T pickup baler also bales from the stack. Pickup width is 54 inches. Twin knotters are used for tying heavy baler twine.

EMBLEM OF INCO SERVICE
TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes and other alloys containing Nickel. This information is yours for the asking. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Another Chore for
WISCONSIN Air-Cooled ENGINES!

Almost every day unique new jobs, handled by ingenious new equipment, are being presented for mechanization by Wisconsin Air-Cooled Engines. Click's Post Peeler, Lake City, Fla., for example, has been designed and built for large volume post-peeling production with minimum labor and power.

Powered by a single cylinder Wisconsin Air-Cooled Engine, this machine, operated by one man, will peel from 250 to 350 posts per day . . . which figures about 1 minute per post, including the time it takes to pick the unpeeled post off the stack and put the peeled post on another.

Include a Wisconsin Engine as integral power for your equipment, for design adaptability and operating dependability.

WISCONSIN MOTOR Corporation
MILWAUKEE 14, WISCONSIN
WORLD'S LARGEST BUILDERS OF HEAVY-DUTY AIR-COOLED ENGINES

BELT LACING and FASTENERS for transmission and conveyor belts

"JUST A HAMMER TO APPLY IT"

ALLIGATOR
Trade Mark Reg. U. S. Pat. Office
STEEL BELT LACING

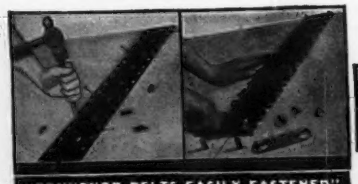
World famed in general service for strength and long life. A flexible steel-hinged joint, smooth on both sides. 12 sizes. Made in steel, "Monel Metal" and non-magnetic alloys. Long lengths supplied if needed. Bulletin A-60 gives complete details.

FLEXCO HD
BELT FASTENERS AND RIP PLATES

For conveyor and elevator belts of all thicknesses, makes a tight butt joint of great strength and durability. Compresses belt ends between toothed cupped plates. Templates and FLEXCO Clips speed application. 6 sizes. Made in steel, "Monel Metal", non-magnetic and abrasion resisting alloys.

By using Flexco HD Rip Plates, damaged conveyor belting can be returned to satisfactory service. The extra length gives a long grip on edges of rip or patch. Flexco Tools and Rip Plate Tool are used. For complete information ask for Bulletin F-100.

Sold by supply houses everywhere


"CONVEYOR BELTS EASILY FASTENED"

FLEXIBLE STEEL LACING CO.
4677 Lexington St.
Chicago, Ill.

PROFESSIONAL DIRECTORY

GEORGE R. SHIER ROBT. J. McCALL
Professional Agricultural Engineering Services
Structures, Ventilation, Drying, Machinery Development and Sales Consultation, Engineering Design
Members A.S.A.E. Room 705, 8 E. Broad St., Columbus 15, Ohio

FRANK J. ZINK ASSOCIATES
Agricultural Engineers
Consultants on product development, designs, research, market research, public relations
FELLOW A.S.A.E. MEMBER S.A.E. Telephone: Harrison 0723 Suite 4300, Board of Trade Bldg. Chicago 4, Illinois

RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Carroll Wm. Andrews, rural service engineer, Southwestern Gas & Electric Co., Shreveport, La.

M. S. A. Baki, general manager, Universal Engineering and Trading Co., Inc., P. O. Box 26, Faggala, Egypt.

Irl A. Daffin, president, New Holland Machine Co., New Holland, Pa.

Henry Z. Düffie, Jr., assistant agricultural engineer, Extension Service, Clemson College, Clemson, S. C.

James D. Eppright, rural service advisor, Texas Power & Light Co. (Mail) McKinney, Tex.

A. Duane Fossum, utilization advisor, Nodak REA, Grand Forks, N. D.

Thamon E. Hazen, graduate assistant in agricultural engineering, Purdue University, Lafayette, Ind. (Mail) 129 North Western Ave.

George B. Hill, head, engineering dept., Dain Mfg. Co., Ottumwa, Iowa.

Robert R. Jones, rural electrification extension specialist, Louisiana State University, Baton Rouge, La.

Allen M. Kough, general manager, Dain Mfg. Co., Ottumwa, Iowa.

George J. Kuehneman, service manager, Aerco Corp., 12024 Center St., Hollydale, Calif.

Edgar F. Moore, Jr., farm and cattle ranch operator, Quinlan, Okla.

Oscar Neunhoffer, Jr., engineering trainee, Caterpillar Tractor Co. (Mail) 1 River Drive, Radio City, North Pekin, Ill.

George L. Penrose, agricultural agent, Union Pacific Railroad, Portland, Ore.

James A. Porter, agricultural technician, research committee, Detroit Agricultural-Industrial Foundation, 320 W. Lafayette St., Detroit 26, Mich.

Sam C. Pursley, student trainee, J. I. Case Co. (Mail) 523 Stewart Ave., Atlanta, Ga.

Elford B. Ray, graduate trainee, Tennessee Valley Authority, Chattanooga, Tenn.

Graydon N. Snyder, agricultural engineer, The Ohio Power Co., 45 S. Monroe St., Tiffin, Ohio.

Leslie B. Thomsen, general line service, International Harvester Co. (Mail) 609 1st St., Watertown, S. D.

George E. Trisler, assistant sales manager, The Deming Co., Salem, Ohio.

Sebastian L. Vogel, assistant extension agricultural engineer, North Dakota Agricultural College, Fargo, N. D.

Norval J. Wardle, assistant professor of agricultural engineering (farm safety), Iowa State College, Ames, Iowa.

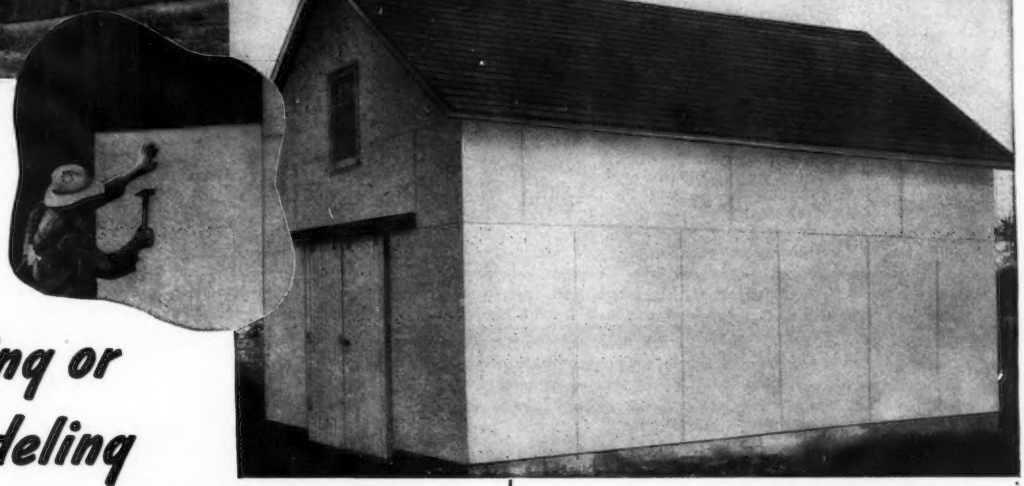
TRANSFER OF GRADE

Philip V. Eshelman, service department, Ford Motor Co. (Mail) 14034 Vaughan, Detroit 23, Mich. (Junior Member to Member)

Verdine D. Rice, vocational agricultural instructor, Wishek High School, Wishek, N. D. (Junior Member to Member)

← **BEFORE:** Run-down, leaky, rotting away . . . yet quickly made modern with 4′ x 8′ sheets of Flexboard *at low cost!*

AFTER: Now a modern, efficient structure with fireproof wall surfaces that will never need painting to preserve them.



For Building or Remodeling Recommend FLEXBOARD

Flexboard is a farm favorite for greater fire-safety, permanence, economy! Made of asbestos and cement, pressed and then repressed for extra strength, Johns-Manville Flexboard is like a sheet of stone. Yet it's flexible—fits curved surfaces. And it's easy to work—saws and nails like wood.

Comes in large 4′ x 8′ sheets—fireproof, rotproof, moisture-proof, rodent-proof—and *inexpensive.*

Flexboard cuts upkeep costs. Its hard, smooth surface is easy to clean, needs no paint or whitewash to preserve it. Can be used inside or out for walls, roofs, floors, or ceilings on new or remodeled structures.

A free research service—Johns-Manville maintains one of the most complete research laboratories in the world for building materials. If you have a special problem on farm building or research, write to the farm division. J-M will gladly work with you to the full extent of its facilities.

Because of the unprecedented demand for Johns-Manville Building Materials, there may be times when we cannot make immediate delivery. We therefore urge everyone to anticipate requirements as far in advance as possible.

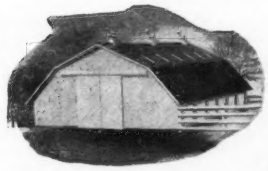
Are your files up-to-date?

Do you have the Johns-Manville printed material listed here?

1. Flexboard on the Farm
2. Farm Idea Book
3. Agricultural Handbook
4. Maintenance & Repair Manual
5. Farm Building Plan Service
6. Low-Cost Farm Structures

Indicate the literature you want and write to Johns-Manville, Dept. AE-10, P. O. Box 290, New York 16, New York.

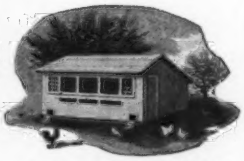
ASBESTOS FLEXBOARD —for every type of Farm Building



Hog Houses—Flexboard on the exterior walls makes a low-cost, weather-tight building.

Dairy Barns—Inside or out, Flexboard saves money because it needs no painting or whitewash to preserve it—or keep it sanitary.

Machine Sheds—Flexboard walls and roof provide quick, low cost, yet permanent construction.



Milk Houses—Flexboard is easy to wash down. Helps meet the most rigid health regulations.

Laying Houses—Flexboard helps fight poultry diseases because it's easy to clean, easy to disinfect.

JM Johns-Manville *Asbestos* **FLEXBOARD**

Protecting Crops, Machinery, Homes SISALKRAFT Does It

On farms — like any other business — every dollar saved is that much profit. Wind, rain, sleet, snow — exposure of every kind — can do much damage to harvested crops, machinery, buildings. With Sisalkraft much of this loss can be avoided.

Sisalkraft is ideal for temporary silos — emergency storage of grain — covering hay stacks — protecting machinery — curing concrete — lining poultry houses — protecting the home — plus many other uses. Costs little. Tough, tear-resistant, and waterproof. Can be used again and again.

Sisalkraft is sold through lumber dealers everywhere. Write for folders on Sisalkraft's many farm uses.

THE SISALKRAFT CO. 205 W. WACKER DRIVE, CHICAGO, ILL. NEW YORK SAN FRANCISCO LONDON SYDNEY

Manufacturers of SISALKRAFT, FIBREEN, SISALATION, SISALTAPE AND COPPER-ARMORED SISALKRAFT

EWC WHEELS

Engineered for YOUR Product

There is a wide variety of EWC wheels and axles for every type of mobile equipment . . . one or several may be ideally suited to your product. For unusual wheel problems, we offer you a complete engineering service, with a thoroughly experienced staff and unexcelled facilities. Write today for complete information.

ELECTRIC WHEEL CO., Quincy, Illinois, Est. 1890

Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail. For further information see the issue of AGRICULTURAL ENGINEERING indicated.

Attention is invited to the desirability of checking on the housing situation when considering a new location.

POSITIONS OPEN: 1946 JUNE — O-506. SEPTEMBER — O-516. NOVEMBER—O-523. DECEMBER—O-526. 1947 MARCH—O-543. APRIL—552, 555, 556, 557. MAY—O-559, 564. JUNE—O-567, 569, 571. JULY—O-574. AUGUST—O-576, 577, 579. SEPTEMBER—O-581, 582, 584.

POSITIONS WANTED: 1946 FEBRUARY—W-207. MAY—W-309. JUNE—W-320. SEPTEMBER—W-337. 1947 FEBRUARY—W-373. APRIL—W-386, 387, 389. MAY—W-394, 395, 398, 100, 101, 103. JUNE—W-104, 105, 106. JULY—W-112. AUGUST—W-114, 116, 117, 118. SEPTEMBER—W-119, 120, 121.

NEW POSITIONS OPEN

DESIGN ENGINEER, for agricultural implement design and engineering, with large full-line manufacturer in the Midwest. BS deg in mechanical engineering, or equivalent. Experience in creative mechanical design in farm implement field, and in engineering administration. Usual personal qualifications for commercial design. Opportunity for advancement governed largely by individual. Age, 30 - 45. Salary open. O-585

EXTENSION AGRICULTURAL ENGINEER (instructor or assistant professor rank) for work in farm structures, in midwestern state college. BS deg in agricultural or architectural engineering. Farm background and as much experience as possible in the general field of farm structures. Ability to work with others and to talk to fairly large groups. Opportunities for advancement in accordance with general college policy. Age, 25 - 35. Salary, $3000 - $3700. O-586.

JUNIOR ENGINEER (experimental) (4 openings), for development of experimental implements and parts, under direction of supervising engineer. Location, middle west. BS deg in mechanical engineering, or equivalent. Experience determines beginning status as trainee or junior engineer. Must show initiative, cooperation, and loyalty. Opportunity for advancement to senior engineer or supervising engineer. Age, 22 - 40. Salary open. O--587.

PROJECT ENGINEER for redesign on machines now being manufactured. Location, Midwest. BS deg in agricultural or mechanical engineering. Experience in mechanical design, preferably in farm machinery, with knowledge of materials and ability to make layout drawings. Rural background and ability to work with others. Permanent position for right man. Age, 25 - 45. Salary open. O-588

IRRIGATION ENGINEER (assistant professor rank) for teaching and research in irrigation in a western state university. Advanced degree required, either ME, CE, or PhD. Evidence of ability in research. Salary, $4,500. O-589.

ALLIS-CHALMERS Mfg. Co., Harvester Works, La Porte, Ind., has openings for several men with design experience on corn, grain, hay, or silage harvesting equipment. O-590

ASSISTANT DEPARTMENT HEAD for work in procurement and distribution of farm electrical equipment to regional cooperatives. BS deg in agricultural engineering. Business experience and working knowledge of electrical equipment. Ability to work with buyers. Age, 28-35. Salary open. O-591.

NEW POSITIONS WANTED

AGRICULTURAL ENGINEER desires sales or service work in farm power and machinery field. BS deg in agricultural engineering, University of Wisconsin, 1947. Farm background, and Army Air Corps experience as Master Sergeant in charge of 100 to 150 maintenance men in engineering section of a heavy bomber squadron. Minor disability (10 per cent) due to arthritis in back. Available now. Married. Age 32. Salary, open. W-122

AGRICULTURAL ENGINEER desires research or development work in farm equipment industry. BS deg in agriculture, 1941, BS deg in agricultural engineering expected January, 1948, University of Nebraska. Two years teaching farm power; three years undergraduate laboratory assistant in farm power. More than 3 years commissioned naval service. No physical defects. Available Feb. 1, 1948. Married. Age 29, Salary, open. W-123.

AGRICULTURAL ENGINEER desires research or development work in power and machinery or rural electric industry. BS deg in agricultural engineering, 1942, Virginia Polytechnic Institute. Two years as special engineer on electrical and mechanical maintenance of open hearth heavy machinery, Carnegie-Illinois Steel Corp. Enlisted and commissioned war service in Army. One year as salesman of farm and orchard equipment. No physical defects. Available now. Married. Age 27. Salary $3600. W-124